Autumn 1958

Artificial Limbs

A Review of Current Developments

PROSTHETICS RESEARCH BOARD

National Academy of Sciences
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The NYU Field Studies—A Postscript

EUGENE F. MURPHY, Ph.D.[1]

Well, one of the two (who will soon be here)—
But *which* of the two it is not quite clear—
Is the Royal Prince you married!
Search in and out and round about
And you'll discover never
A tale so free from every doubt—
All probable, possible shadow of doubt—
All possible doubt whatever!
—*W. S. Gilbert, 1889*

In preparing a report on extensive research, a modern investigator faces the same problems as the Grand Inquisitor. He may be able to furnish explicit answers to all the minor questions and to delimit the possible solutions of major problems. Only in fortunate circumstances can he provide final answers to all the questions originally posed.

This, the second of two issues of Artificial Limbs to be devoted to the NYU Field Studies of 1953–55 (see issue for Spring 1958), offers a wealth of censuslike information on fascinating problems revealed in the course of studying extraordinarily large samples of upper-extremity amputees and their prostheses. It answers with overwhelming affirmation a critical and highly pertinent question: *Do* modern concepts of upper-extremity prosthetics truly represent substantial improvement over previous practices? But this favorable broad conclusion demands by virtue of its own importance respect for certain essential qualifications more or less obvious from the circumstances of study if not from the nature of the study itself.

Largely because the samples in the NYU Field Studies included such high percentages of veterans of World War II and Korea, many of the amputees treated had already received organized care and training in military amputation centers. Moreover, many had already reaped some early benefits of the Artificial Limb Program. New and supposedly improved devices and techniques had already been developed and applied progressively over a period of half a dozen years, and the U. S. Veterans Administration was already operating Orthopedic and Prosthetic Appliance Clinic Teams in some 30 key cities. Though at the time members of these clinic teams were concerned largely

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with the suction-socket program and with lower-extremity problems generally, they were so stimulated by the special courses at UCLA, and so encouraged by the monthly visits of NYU field representatives, as to tackle problems in upper-extremity prosthetics and to expand their perspective from simple application of mechanical gadgets to genuine concern for all aspects of the resulting man-machine system. And consequently the results here given are clearly weighted by disproportionate inclusion of the comparatively young and otherwise healthy adult male with special advantages not ordinarily then to be had by the amputee population at large.

The nature of the subject matter is something else again. In any investigation so intimately associated with the individual proclivities of human beings, and particularly one of the magnitude indicated, the variables to be controlled are many and diverse, and the data to be had are especially voluminous. Although census counts may provide clues to major influences, and although modern electronic computers may furnish effective correlations and satisfying proof of statistical significance, prosthetics problems in clinical practice are not apt thus to be fully solved because, as in polio, cancer, and numerous other kinds of human disorder, there is generally no single "necessary and sufficient condition" but instead a rather large number of interrelated factors which, added or subtracted in proportions variously weighted, may easily tip the balance for or against clinical usefulness and research success. Thus effective application of the present findings calls for the exercise of keen discrimination over and above that required by the limitations of the sample studied.

Despite the existing correlations, therefore, the NYU Field Studies leave unsolved, or at best still subject to serious debate, some disquieting major questions. Why, for example, did a few amputees prefer their old arms over the newer ones? How well did the new prostheses pass the comfort aspects of the checkout tests required? Are the checkout standards adequate? Were complaints about terminal devices heavily correlated with mechanical failure? Of many such puzzlers, some might be resolved by further analysis and correlation of the mountainous data now embalmed in the form of 29 punched cards for each of several hundred amputees. Others indicate the need for further research in the social sciences, while still others constitute a continuing challenge for designers of devices, developers of techniques, and sponsors of research.

Perhaps even more fascinating than the yet unsolved questions of physical and mechanical significance are the hints at the nature of amputee psychology. Still needed are thoughtful studies of the problems of realistic acceptance of amputation losses, of objective appraisal of the possibilities for rehabilitation, of the influence of amputee expectations on success in restoration, and of the potentialities for improvement through counseling and guidance both for the patient and for the public as regards attitudes toward what is still called

"handicap." Serious consideration of some of the points raised in the present volume may be expected to temper success with humility and hence possibly to afford a degree of wisdom not otherwise to be had. Here, then, is a by-product perhaps more valuable in the long view than are the actual conclusions it is now possible to formulate.

In these investigations, NYU faced and overcame in the conduct of its own studies many practical difficulties in addition to the complex problems inherent in investigations in limb prosthetics. It recruited from a highly restricted labor force a field staff of persons able to observe and assess clinical procedures effectively and willing to travel two weeks in every four during a period of uncertain tenure. It thereby quickly established relationships with VA facilities throughout the country and, even more important, with the numerous private clinic teams that NYU helped to foster, and it maintained checkout standards despite differences in interpretation from one clinic to another. The correlations and insights here presented have all come from the very persons who helped to collect the data, and the summaries have all been prepared with the help of former field men who have since transferred to other NYU projects or who have now left the NYU facilities entirely.

Recognizing residual deficiencies, facing unresolved problems, and yet expressing gratitude for the substantial achievements described in NYU's unprecedented two-number contribution to ARTIFICIAL LIMBS, we may now, in the acknowledged infancy of the art and science of limb prosthetics, justifiably substitute "books" for "babes" in the familiar characterization by the Grand Inquisitor:

> Both of the babes were strong and stout,
> And, considering all things, clever.
> Of *that* there is no manner of doubt—
> No probable, possible shadow of doubt—
> No possible doubt whatever.

Studies of the Upper-Extremity Amputee

V. The Armamentarium

EDWARD R. FORD, C.P.,[1] AND
EARL A. LEWIS, M.A., R.P.T.[2]

ONE of the most interesting aspects of the evaluation procedures is concerned with comparisons between the prosthetic equipment worn by the participating amputees prior to the NYU Field Studies and that later provided as part of the studies. Some amputees entering the program were found to be wearing modern arms based on the latest components and materials and constructed according to the latest methods of fabrication. Others had outmoded and sometimes outworn prostheses. And a third group either had never worn prostheses before or else were not wearing a prosthesis at the time the program began. Accordingly, the data gathered were not only on the new program prostheses but also on the old arms previously worn, if any, and hence the present analysis deals not only with the effects of program arms but also to a considerable extent with comparisons between the old and the new prostheses.[3] Of the 1630 arm amputees involved in the NYU Field Program, 359 were available for comprehensive investigation throughout the period covered by the evaluation studies. Of the 359, which together form the basis for this discussion, 168 were below-elbow amputees, 158 were above-elbow amputees, 23 had shoulder disarticulations, and 10 were bilaterals. Those who had prior experience with prostheses were used to form the comparative analysis of old *vs.* new.

Although the subjects making up the group were generally available for intensive study, it was not possible to obtain from every amputee an answer to every question. In other instances, the investigators received multiple responses to questions. Moreover, certain areas of investigation called for responses in relation to the number of components involved, in which case the number of responses varied with the bilateral group and with those patients who utilized more than one terminal device. Although the reflection of these factors in the data causes some inconsistency in numbers of replies, it does not reduce the over-all value of the results.

For purposes of identification, all prostheses worn by the amputees prior to inception of the NYU Field Studies are here referred to as "old prostheses" or "preprogram arms," although in a few cases they were rather new and reflected some of the latest techniques and components. All prostheses fitted during the course of the research studies are identified as "program" or "new" prostheses, although some of the components and techniques had for some time enjoyed either limited or general use in the prosthetics field. While the "old prostheses" represent an admixture of various techniques and components, some old, some new, the "program prostheses" represent the best of the old plus the latest innovations in the field of limb prosthetics at the time.

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[3] The data reported here were all recorded on forms similar to those shown in Appendices IIB, IIIA, and IIID of the issue of ARTIFICIAL LIMBS for Spring 1958 (pp. 25-28, 29-31, and 40-45).

In passing, it should perhaps be noted that the data concerned were for the most part gathered on program prostheses fabricated shortly after the prosthetists' completion of the prosthetics courses at the University of California at Los Angeles. The skills and experience available for handling the latest components, materials, and techniques were therefore somewhat limited during the early days. As experience and attendant skills increased, the quality of the prostheses improved. No apology for the program treatment procedures and prostheses (which, as will be seen, were clearly superior to preprogram efforts), this circumstance indicates that expansion of present gains can be expected as prosthetists and prosthetics clinics continue to accumulate experience with latest procedures.

Terminal Devices

The artificial hand or hook is generally considered to be the most important single component of an artificial arm. A major functional purpose of all other components of the upper-extremity prosthesis is to make it possible for the terminal device to be positioned and the function of grasp to be utilized. Moreover, the hook or hand is important from the standpoint of aesthetics, since it is exposed to view almost constantly and is a matter of curiosity to all who recognize it as a prosthetic device. Today's prosthetic armamentarium presents a choice, from a selection of hooks and hands, of terminal devices most likely to meet the wearer's needs. Within this framework are devices which operate on the voluntary-opening or the voluntary-closing principle (*3*). Available hands are either essentially cosmetic or else are designed to provide prehension as well as cosmesis (*6,7*). Either type permits the functions of pushing, pulling, and holding down objects.

Were any one of these devices completely satisfactory, it would enjoy exclusive use by all wearers of arm prostheses. Since such is not the case, amputees frequently interchange two or more terminal devices, say a hand and a hook, and some even interchange two hooks of different shapes and operational characteristics. In any event, many factors influence the selection of terminal devices (*2*), so that whatever is chosen usually represents a compromise based upon consideration of the psychological, environmental, and biomechanical circumstances of the individual amputee.

THE APRL HAND AND GLOVE

One of the most widely publicized developments in the Artificial Limb Program has been the APRL voluntary-closing terminal devices —the APRL hook and the APRL hand with its companion glove of plasticized polyvinyl chloride (*3,6,7*). Prior studies (*8,9*) had established the usefulness of these devices, and the Upper-Extremity Field Studies presented a unique opportunity to introduce these items into many more clinics over the country and to obtain additional information concerning the value of the devices to amputees. The APRL hand was therefore prescribed in almost all research cases where a prosthetic hand was indicated (285 out of 291). Four patients expressed strong desires to continue with voluntary-opening hands, while two others elected to continue with passive, cosmetic hands.

Tests showed that grasp forces available with the APRL hand, in which grasping force is related directly to the force that can be exerted by the wearer, were much higher than those to be had with other types of functional hands. Almost all wearers of the APRL hand (89 percent) could exceed 20 lb., a force not uncommon in the palmar prehension of non-amputees (*11*). Voluntary-opening mechanical hands, in which the force is limited to that available from springs or rubber bands, showed a maximum prehension force of 5 lb.

When these tests were completed, the subjects were questioned regarding their reactions toward the APRL hand in the areas of usefulness, appearance, ease of operation, and weight.

Usefulness

Most of the amputees considered the APRL hand to be a useful device or at least one of limited use. Less than 12 percent considered the hand to be of no use. But the pattern of responses clearly indicates that the hand becomes less useful to the wearer as the level of amputa-

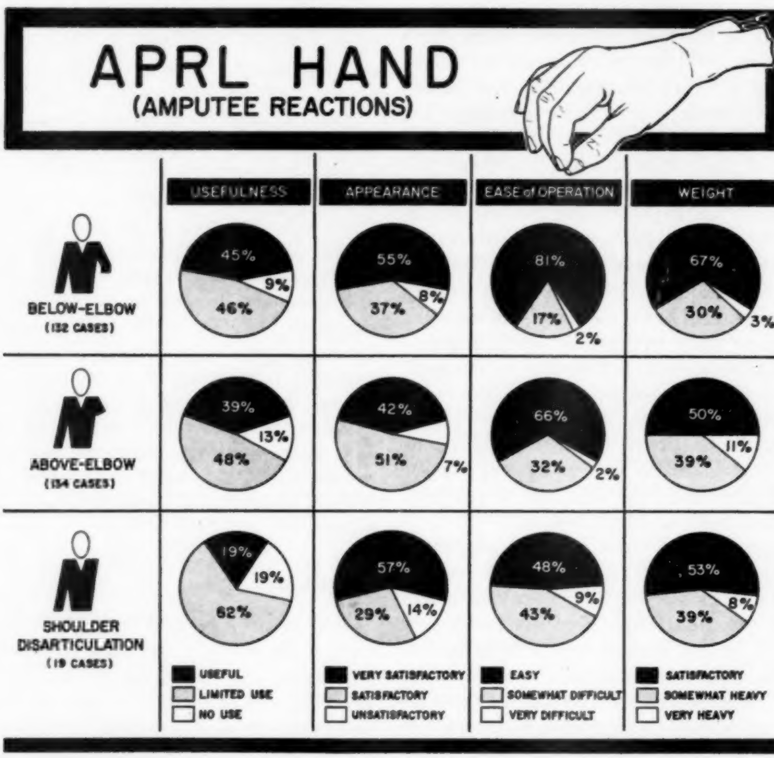
tion becomes higher, presumably owing to the increased difficulty of using a prosthesis with decreasing stump lengths.

The ability to control grasp and to maintain it (by automatic locking) was well received by 50 percent of the amputees for whom APRL hands had been prescribed, and increased function over a wide range of activities elicited important voluntary comments from another 27 percent. The choice of using either the large or the small finger opening prompted positive comments by 11 percent of the sample. When comparisons were made of the amputee reactions to usefulness, the APRL hand was rated considerably higher than other types of hands previously worn.

Appearance

Noted was an exceptionally high degree of amputee satisfaction with the appearance of the APRL hand. As might have been expected, level of amputation did not seem to influence the wearers' reactions in this area. More than 90 percent of all the amputees felt the APRL hand and glove to be either "very satisfactory" or "satisfactory" in appearance. In no other component of the prosthesis do we have such a large number of amputees exhibiting this degree of positive response.

The size of the APRL hand was felt by 6 percent of the wearers to be a problem. Discoloration and difficulty in keeping the glove clean elicited negative comments from 12 percent of

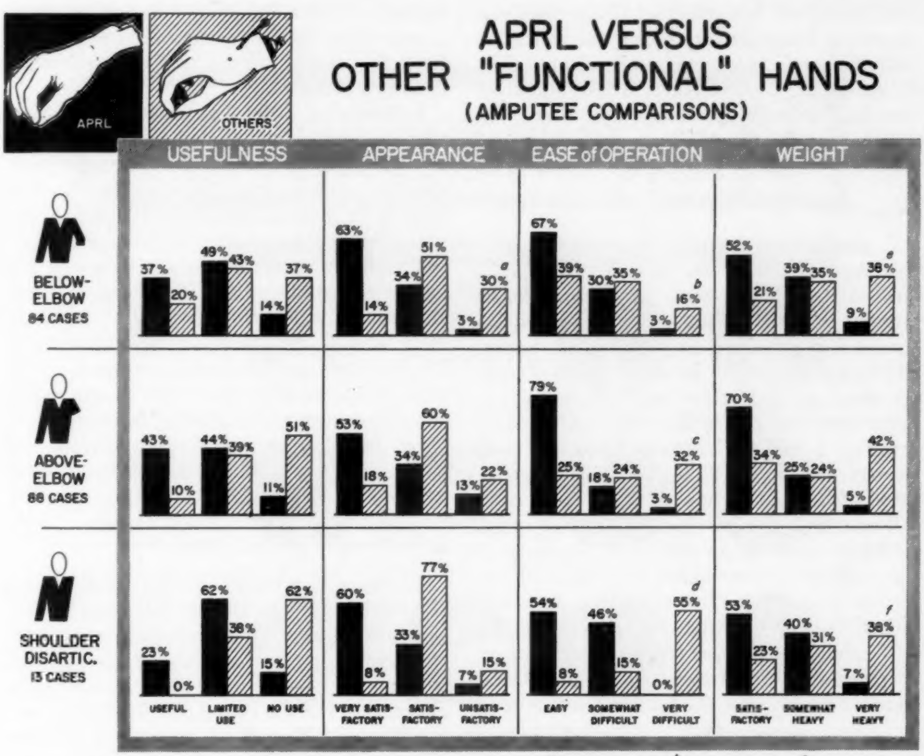


the subjects. Poor wear characteristics of the glove (abrasion, tearing, rubbing through) elicited negative comments from 9 percent of the sample. When amputee reactions to the appearance of the APRL hand were compared with the corresponding reactions to the appearance of other hands previously worn, the results were very favorable toward the APRL device.

Ease of Operation

Almost 72 percent of the amputees for whom an APRL hand had been prescribed felt that it was easy to operate, another 26 percent considered it somewhat difficult to operate, and less than 3 percent found it very difficult to operate. Below-elbow amputees experienced the least difficulty in hand operation. As expected, fewer found the APRL hand "easy" to operate as the level of amputation became more proximal.

Some of the amputees had worn other "functional" hands prior to the APRL device. When they compared ease of operation of their old prosthetic hand with that of the APRL hand, the APRL model was preferred. It is interesting to note that the shoulder-disarticulation and above-elbow cases exhibited dramatic changes in their reactions to use of functional hands, a fact which would suggest that the APRL hand has much greater applicability than the older hands. For one thing, in the dual-control system (*10,11*) the cable-excursion requirements are lower for voluntary-closing devices than for voluntary-opening devices,



[a]*Not responding, 5%;* [b]*Not responding, 10%;* [c]*Not responding, 19%;*
[d]*Not responding, 22%;* [e]*Not responding, 6%;* [f]*Not responding, 8%.*

and this circumstance exerts an important influence on the use of above-elbow and shoulder-disarticulation prostheses. Apparently the additional control motions needed for operation of voluntary-closing devices did not constitute an objection insofar as ease of operation was concerned.

Weight

Judging from amputee opinions relating to the weight of the APRL hand (15 oz. with glove), the below-elbow group found the weight more satisfactory than did any other. In view of the greater residual anatomy in the below-elbow case, this result is generally understandable even though the short below-elbow case, without assistive forearm lift (*1,10*) is at a disadvantage. It is significant to note that 42 percent of all amputees for whom a hand had been prescribed felt that the APRL hand was somewhat heavy or very heavy, an indication that further improvements, aimed at weight reduction, are needed. Nevertheless, amputees who had worn other hands considered the APRL hand lighter. All in all, the wearers' reactions consistently favored the APRL hand.

Discussion

It should be understood that amputee reactions toward the APRL hand were of special interest to the research program. Consequently, many such hands were prescribed not for specific vocational or avocational reasons, nor because of patient interest, but to observe the effects upon a rather large number of amputees who had no specific objections to being fitted on a trial basis. Many confirmed hook wearers were therefore included in the group fitted with APRL hands.

The data show that mass fitting (285) of the APRL hand caused an additional 27 percent of the patients to wear hands on a more or less regular basis. Very few amputees expressed serious over-all negative feelings toward the APRL hand and glove.[4] Apparently, however, 25 percent of the patients for whom APRL hands had been prescribed wore them less than one day a week. Some, after a brief experience with the hand, declined to wear it at all and preferred to return to exclusive use of a hook. Since this response cannot be related to any specific dislike for the APRL hand and glove, it appears to relate more to a basic preference for a hook.

A number of improvements in the APRL hand were suggested during interviews with the amputees. One was that a range of sizes would be most welcome since the one size available at the time was often either larger or smaller than the corresponding normal hand. Amputees with large hands seemed to feel that the APRL hand and glove were too small and effeminate. Another, cited especially by those with the higher levels of amputation, concerned the need for reducing the weight of the APRL hand. Other proposed improvements related to appearance and durability (especially of the glove) and to the complexity of function arising from the double control motion required for locking and unlocking.

In brief, the APRL hand, with its two-position prehension range, its voluntary-closing self-locking mechanism, and its cosmetic glove, showed superior grasp forces and was considered to be more useful, easier to operate, and much better in appearance than other mechanical hands. Although the wearers indicated that weight reduction in the APRL hand would be welcomed, the existing hand was considered more satisfactory than other mechanical hands. Despite these positive findings, it was apparent that design changes directed toward weight reduction, improved durability in the cosmetic glove, establishment of a range of sizes, and simplification of operating requirements would improve the device significantly.

RUBBER-BAND-LOADED HOOKS

The type of hook which, historically, is the standard in the prosthetics field, and the one to which all other designs are compared, is the steel or aluminum voluntary-opening split hook in which the fingers rotate about a single pivot and are held in the closed position by the contraction of rubber bands that stretch during opening (*2*). Addition of more and more rubber bands increases the maximum available finger forces at the expense of added work in opening.

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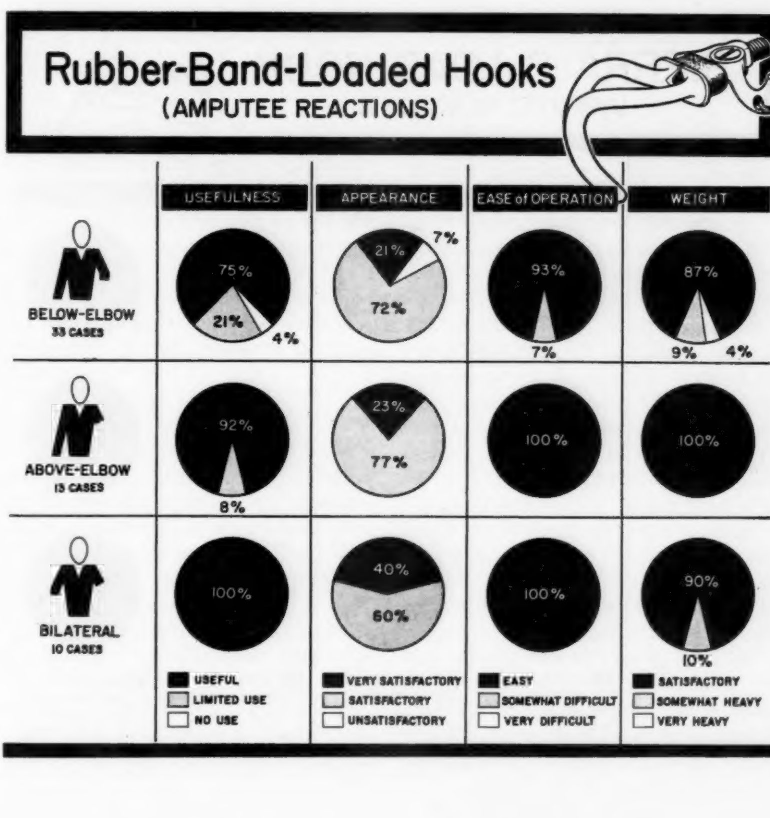
[4] Less than 3 percent had over-all negative reactions to the hand; 6 percent had over-all negative reactions to the glove.

Many variations in finger shape are to be had. Some fingers are lined with rubber to reduce slippage, others are unlined. In the studies concerned, prescription of rubber-band-loaded hooks was often on the basis of previous amputee experience. Sometimes clinical judgment favored them, especially for use with bilaterals, because of the simplicity of operation as compared with voluntary-closing, self-locking terminal devices which, although superior in grasp forces, demand additional control motions, a requirement generally considered to be a shortcoming. In tests involving 68 of these simple hooks as worn by amputee subjects, it was found that the rubber bands had been selected to yield prehension forces ranging from 1 lb. to 14 lb. (average, 4.3 lb.), depending on individual preference.

With regard to usefulness, appearance, ease of operation, and weight, amputee reactions to rubber-band-loaded hooks are rather consistent regardless of level of amputation. Although in general there is a high degree of acceptance, 21 percent of the below-elbow amputees and 8 percent of the above-elbow cases indicated that rubber-band-loaded hooks are of limited use only. Thus again improvement is needed. The subjects themselves suggested more durable rubber inserts for the fingers, elimination of rubber bands, and reduction in the conspicuousness of the hook without reducing its functional value.

SIERRA TWO-LOAD HOOK

A relatively new design for voluntary-opening hooks, which traditionally have used rubber bands for closing, is the Sierra two-load hook featuring a spring to close the fingers (*2,3*). Heavy or light closing forces are selected by positioning a small mechanical switch



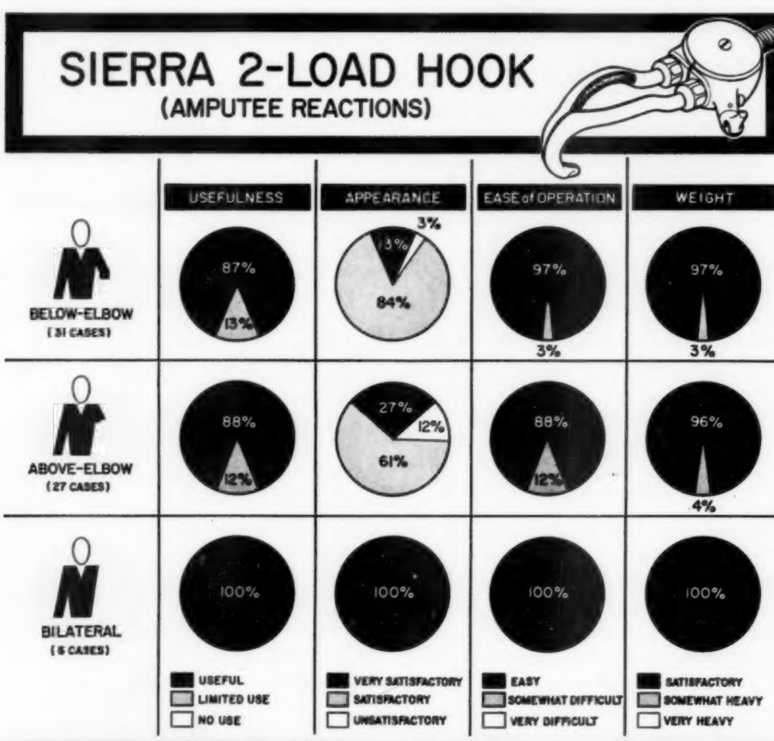
located on the post provided for attachment of the control cable. The case which houses the operating mechanism is made of aluminum, and the hook fingers, also of aluminum, are lyre-shaped and lined with neoprene for increased security of grasp.

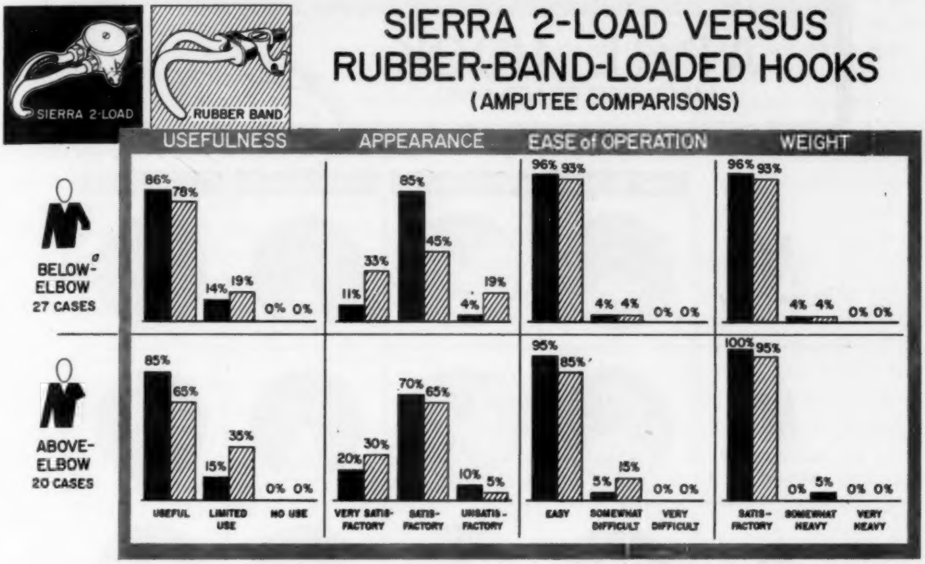
The novel design of the two-load hook, with its simplicity of operation (voluntary-opening) and choice of two grasp forces, interested both clinics and amputees. Consequently, 64 of these devices were prescribed in the study. Data taken on 51 subjects show that pinch forces averaged 3.4 lb. for the light-load setting of the mechanism, 6.6 lb. for the heavy loading.[5]

[5] The prehension forces of the two-load hook are predetermined at time of manufacture and are not readily adjustable as are those in the simpler hooks, where rubber bands can be added or removed.

Amputee reactions to the two-load hook were generally positive insofar as usefulness, ease of operation, weight, and, to a lesser extent, appearance were concerned. As with rubber-band-loaded hooks, there were indications of need for improvement, for 13 percent of the below-elbow amputees and 12 percent of the above-elbow cases indicated that the two-load hook was of limited use only. That 12 percent of the above-elbow amputees felt the device somewhat difficult to operate is a finding hard to interpret, unless perhaps these particular subjects had been accustomed to extremely light loadings on hooks operated by rubber bands.

In general, there was a favorable reaction toward the availability of two levels of grasp force from which to select. Although apparently the light load was used most often, the wearers found that the heavier loading was





[a] *In below-elbow cases wearing rubber-band-loaded hooks, 3% of the wearers did not respond.*

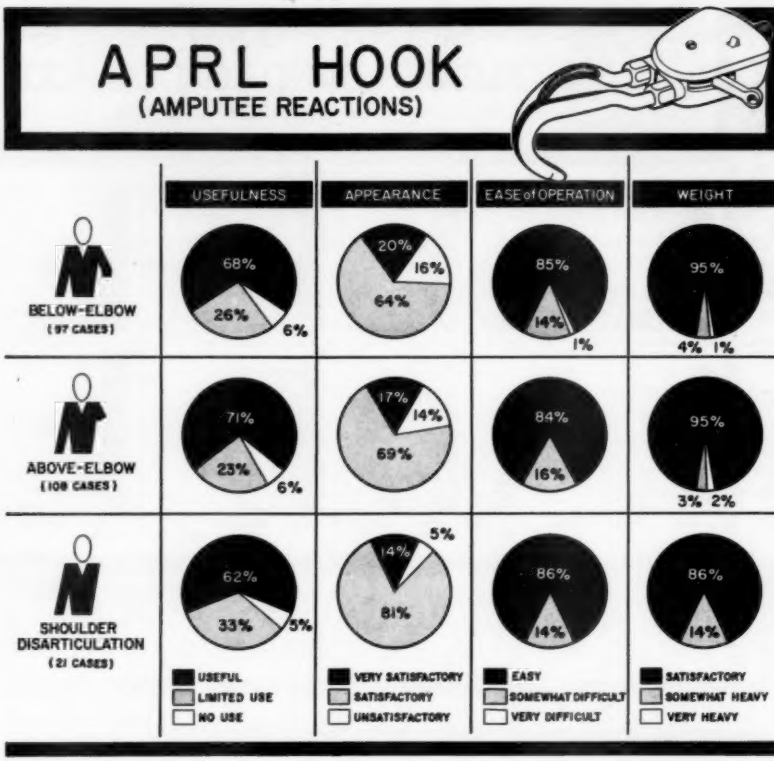
sometimes very desirable. The indications were that a desirable improvement could be effected if the ranges of prehension force could be made adjustable by the wearer (perhaps by use of a simple tool). When amputee comments were compared (two-load hook versus rubber-band-operated hooks worn previously), there was no clear-cut preference for either type, although the two-load fared slightly better in all areas except appearance.

APRL HOOK

The APRL hook is, like the APRL hand, a voluntary-closing, automatic-locking terminal device (*3*). The body and fingers are of aluminum to keep weight within reasonable limits, the fingers being lyre-shaped and lined with neoprene to increase the security of grasp. Opening ranges of approximately 1½ in. or 3 in. are selected by manipulation of a small switch protruding from the hook case. The control cable attaches to a lever arm projecting from the side of the housing for the mechanism. As with the APRL hand, prior studies (*8*) had established the general acceptability of the hook, and the NYU Field Studies presented a unique opportunity to gain additional insight into its application and to introduce it into more clinics throughout the country.

The basis for prescription was to furnish the APRL hook in a majority of cases where a hook was required. The only exceptions were those cases where a clear contraindication was apparent (for example, in cases of patient refusal to wear any type of hook, or to change from some other type to the APRL hook, or where occupational requirements demanded extremely rugged construction, or where the subject was interested in trying the Sierra two-load hook). Consequently, rather large numbers of amputees in the study were equipped with the APRL hook.

The data obtained with 228 hooks were similar to those obtained with the APRL hand when it was compared to voluntary-opening hands. Grasp forces were found to be considerably higher with the APRL hook than with voluntary-opening hooks. Eighty-nine percent of the wearers could exert forces over 9 lb., 54 percent over 20 lb.



Although amputee reactions to the APRL hook were generally positive, the present design evidently leaves much to be desired in the area of appearance and, to a lesser degree, in the area of usefulness. In interviews, the amputees mentioned:

1. The possibility of reducing length and bulk by incorporating the terminal-device mechanism in the forearm.

2. Dissatisfaction with the reliability of operation (locking after closing), although some wearers were generally aware that the fault might lie with themselves in not permitting the mechanism to alternate.

3. Backlash, which in varying degrees caused some wearers distress.

4. The potential advantages (aesthetic as well as functional) of having the hook "thumb" as well as the moving finger on the medial aspect. At present, when the "thumb" is on the medial side the moving finger is on the lateral side and opens away from the wearer's body. If the wearer wants the moving finger to open toward him, the "thumb" is placed on the lateral side.

Some interesting points are observed when we compare the responses to the APRL hook with those to the APRL hand. Since in general hooks are conceded to be more functional than artificial hands, it comes as no surprise that in the area of usefulness the APRL hook rated higher than did the hand. As regards appearance, reactions were much more favorable to the hand than to the hook, but, in the case of the latter, amputation level had no apparent effect on amputee feelings. In any event, a significant number of patients found both hand and hook unsatisfactory in appearance.

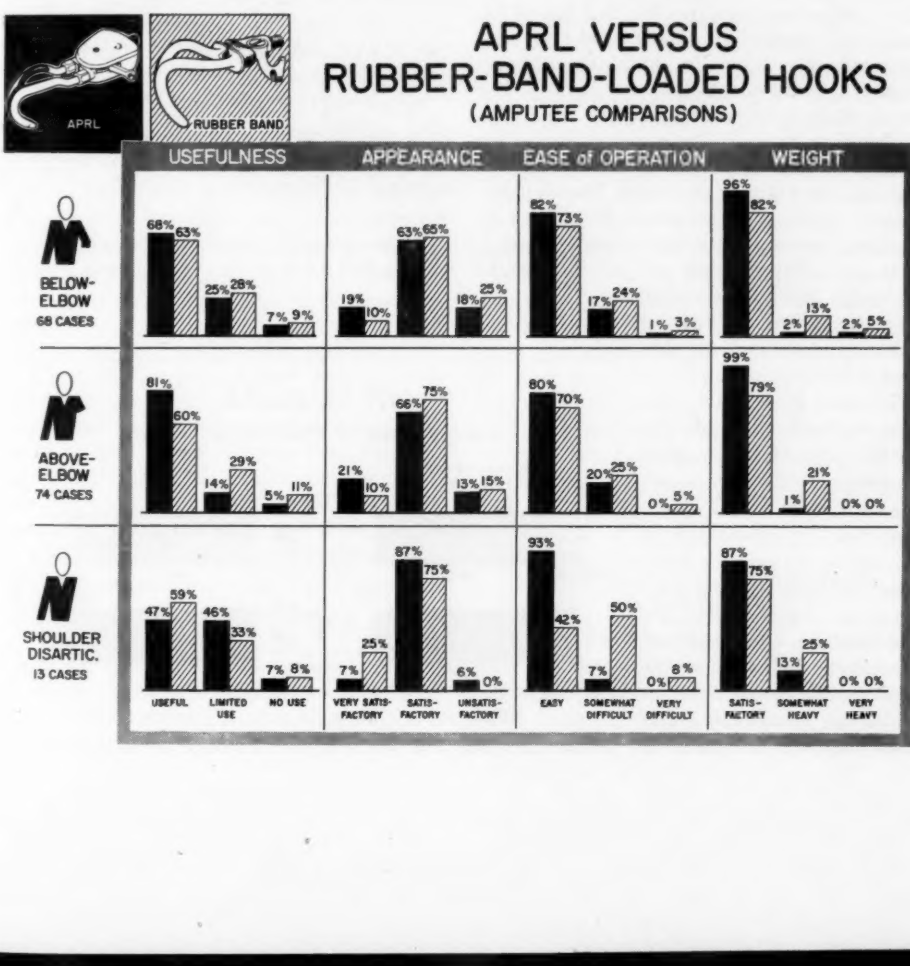
More than 80 percent of the amputees wearing the APRL hook indicated that it was easy to operate regardless of amputation level. Conversely, responses by wearers of the APRL hand indicated that operation became somewhat more difficult at the higher levels of limb loss. By far the majority of wearers registered

satisfaction with the weight of the hook (8¼ oz.), whereas the weight of the gloved hand (15 oz.) was less well received. The higher the level of amputation the more critical weight became.

Next to be considered are the reactions voiced in regard to the usefulness, appearance, ease of operation, and weight of rubber-band-loaded hooks (voluntary-opening) worn prior to the studies and of the APRL hook (voluntary-closing) supplied during treatment. The below-elbow and shoulder-disarticulation wearers considered the rubber-band and APRL hooks approximately equal in usefulness, while the above-elbow wearers felt the APRL hook to be somewhat more useful. As for appearance, about 70 percent of the subjects found both APRL and rubber-band hooks generally "satisfactory." Whereas 15 percent indicated dissatisfaction, the remaining 15 percent said that in appearance both hooks were "very satisfactory." When ease of operation was considered, the below-elbow and above-elbow wearers favored the APRL hook slightly, although both hooks were rated highly with regard to operating characteristics.

The wearers of shoulder-disarticulation prostheses showed a distinct preference for the APRL hook with respect to ease of operation, probably because of the ease with which closure can be effected and because of the low excursion requirements peculiar to voluntary-closing terminal devices. This finding may indicate that rather light prehension forces are used by most wearers of shoulder prostheses, for were this not the case they would react against the difficulty of reopening the hook. There is no indication from the data that the additional control motions required for use of the APRL hook made hook operation less "easy."

Hook weight appeared to present no major problem regardless of level of amputation.



Although the 8¼-oz. APRL hook was generally considered by the wearers to be more satisfactory than the Dorrance No. 555 (3 oz.), the Dorrance No. 5 (7 oz.), or the Dorrance No. 7 (8¾ oz.), the responses may have been influenced by the use of a new prosthesis, which very often was better fitted, more comfortable, and more efficient than the old arm with the rubber-band hook.

It is apparent from the foregoing discussion that functional, split hooks were rather highly valued regardless of type. In all cases, usefulness, ease of operation, and weight were apparently quite acceptable to almost all wearers. Only in the area of appearance did a significant number of subjects indicate dissatisfaction, and even then most of the amputees accepted prevailing appearance.

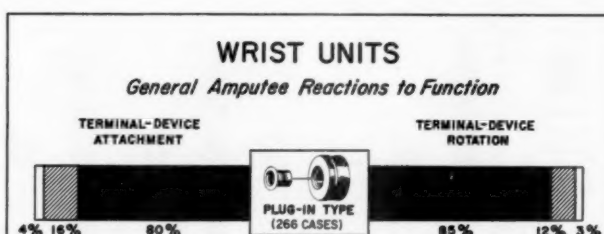
The amputees who used rubber-band-closing hooks prior to the study and changed over to the APRL hook during the study were in an excellent position to compare terminal devices. The below-elbow amputees felt that the APRL hooks and those of the rubber-band type were approximately equal in usefulness, the responses favoring the APRL hook slightly. The above-elbow cases seemed to favor the APRL hook rather strongly, the responses indicating an attitude considerably more positive toward the usefulness of the new hooks. The shoulder-disarticulation cases seemed to favor the rubber-band hooks slightly with respect to usefulness, but the smallness of the sample (13 patients) prohibits drawing any conclusions in favor of either type of hook for this special group.

In sum, it appears that the rubber-band and the APRL types are about equal in usefulness, the data favoring slightly the APRL design. No clear-cut advantage in the use of one over the other is evident from amputee reactions. In all probability, personal preference based on past experience, influence of the clinic team, or other intangibles are contributing factors. The entire area affecting the choice of terminal devices is one that should be given additional study.

Wrist Units

Prosthetic wrist units are designed to facilitate attachment of the hand or hook to the forearm and to permit pronation-supination of the terminal device (*4,5*). The most common type (screw-in type) bears a female thread such as to accept the terminal-device stud, and a rubber washer and retaining plate are used to control the tendency toward excessive loosening or tightening when the terminal device is rotated. A newer type of wrist unit, intended to provide not only for easy rotation but also for easier interchange of terminal devices, incorporates a control button which, when depressed, frees the hand or hook for rotation. Further depression of the control button permits removal of the terminal device from the wrist unit, the need for unscrewing being thus eliminated. In still another wrist, also designed for quick interchange of terminal devices, the turn of a knurled ring releases the hand or hook for rotation or removal.

In the NYU Field Studies, prescription of wrist units favored the button- or ring-operated wrist (plug-in type) wherever more than one terminal device was to be used. When a single terminal device was prescribed, the screw-in type was generally favored, since then interchange was not a major consideration. Plug-in



wrists fitted to 266 research patients and screw-in types fitted to 93 were followed over an average wear period of six to nine months, and amputee reactions were obtained concerning two aspects of wrist function—attachment and removal of the terminal device, and pronation-supination to achieve acceptable attitudes of approach. Of the 359 amputees wearing program arms, those equipped with plug-in units were slightly more satisfied with the attachment function than were those who wore screw-in wrists. Pronation-supination was fairly satisfactory with both types.

Despite the general amputee acceptance of both types of wrist, however, there was also evidence of substantial dissatisfaction. Interviews with the amputees and observation of their performance revealed that a simpler and faster method of exchanging terminal devices was required, as were also improvements in the cable connections, which were then cumbersome and difficult to manipulate with one hand. Evidently, improved rotation mechanisms were needed to permit easy correction of terminal-device attitude for best angle of approach.

When specific wrist features (ease of operation, usefulness, weight, and appearance) were explored (page 16), the wearers were even more positively inclined toward the plug-in wrist unit. The reactions of 138 amputees who had screw-in wrists on their old arms and plug-in wrists on their program arms show that, insofar as exchanging terminal devices was concerned, the plug-in wrists were favored by a greater percentage of the below-elbow wearers than were the screw-in wrists. The opinions of the above-elbow amputees showed only a slight trend in favor of the plug-in wrists. Because only a small number of shoulder-disarticulation cases changed to plug-in wrists, their reactions were not recorded. The responses of 107 amputees who had used screw-in wrists on their old arms and plug-in wrists on the program arms showed that the plug-in type of wrist was considered by below-elbow wearers to be easier to rotate than was the screw-in type.

Opinions concerning the locking function of wrist units are of interest since only the plug-in type locks the hook or hand in its selected attitude, the screw-in type depending upon friction to maintain terminal-device orientation. In 106 cases, both below-elbow and above-elbow wearers considered the plug-in type of wrist (with its ability to permit rotation of the terminal device as well as to lock it) somewhat more useful than the screw-in, nonlocking type.

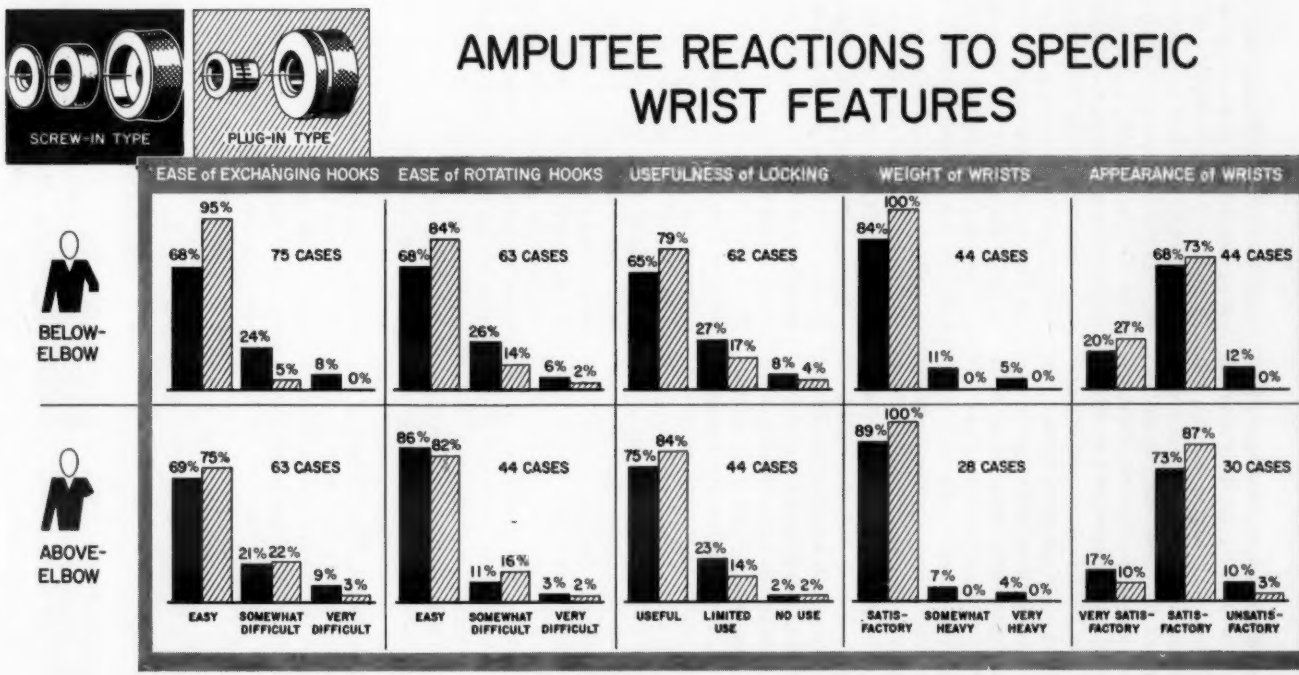
In the areas of weight and appearance, the plug-in type was again, and somewhat surprisingly, favored over the simpler, screw-in unit. Despite the fact that the plug-in wrist is actually heavier than the screw-in type, amputees favor it. Apparently the "halo effect" of the new prosthesis with its generally superior comfort, appearance, and efficiency may be responsible for the positive responses in the areas of wrist weight, wrist appearance, and ease of wrist rotation.

In summary, the plug-in type of wrist was favored slightly over the screw-in type, first because of the relative ease with which terminal devices could be exchanged and second because the hand or hook could be locked in any desired attitude of pronation-supination. Below-elbow amputees seemed to favor the plug-in type more than did the above-elbow group, an understandable result when it is considered that below-elbow wearers are generally more active with their prostheses and more inclined to exchange terminal devices than is the case with above-elbow amputees. In any event, it was apparent from observations and from amputee remarks that improved cable attachments were needed to facilitate ease of connecting and disconnecting hands or hooks. Despite the fact that some below-elbow wearers considered rotation of terminal devices easier with plug-in wrists, observation leaves little doubt but that the screw-in type is superior in rotation features. It seems clear that attitudes toward the rotational qualities as well as toward the weight and appearance of the plug-in wrist were positively affected by concomitant reactions toward superior locking and attachment qualities.

Elbow Joints for Below-Elbow Prostheses

Almost all below-elbow prostheses are suspended from cuffs fitted above the bony prominences of the elbow joint. The cuff and prosthetic forearm are connected by means of mechanical elbow joints, some of which (rigid

AMPUTEE REACTIONS TO SPECIFIC WRIST FEATURES



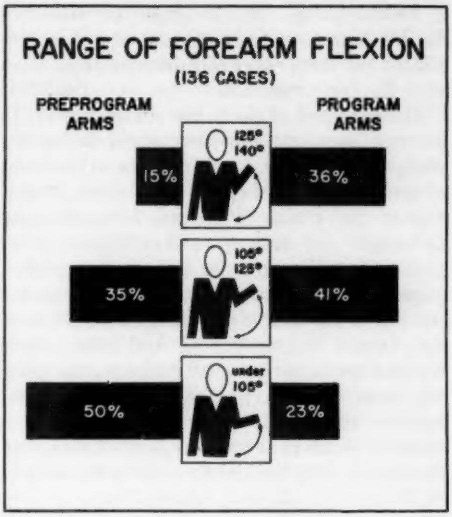
hinges) are designed to permit flexion and extension only, others (flexible hinges) permitting also pronation and supination (*1,4,10*). Metal hinged joints are generally used for shorter stumps where stability against inadvertent rotation is a major requirement. Flexible leather, steel-cable, or fabric-type joints are generally used in prostheses for longer stumps where residual, natural forearm rotation can be utilized. Short stumps typically have limited purchase in the prosthesis and therefore require a snug, high-fitting socket in order to obtain forearm stability (*1*). But the high-fitting socket often restricts the wearer's range of flexion owing to crowding of flesh as the forearm is raised. Special joints, known as "step-up" joints (*1*), are designed to relieve this condition and to produce an increased range of flexion. Since in such a case the range of motion increases at the expense of lifting power, it is sometimes necessary to use an assistive forearm lift similar to that commonly used with above-elbow prostheses (*10*). Whenever the very short below-elbow stump is unsuited for lifting the prosthetic forearm, it is fitted with locking joints actuated either by movement of the stump or by a cable control similar to that used for the above-elbow case (*1*).

Evaluated comprehensively with both old and new prostheses were 136 unilateral below-elbow amputees, the elbow components of the prostheses being as follows:

Type of Elbow	*Old Arm*	*New Arm*
Flexible Hinges	17	74
Rigid Hinges	110	40
Step-Up Joints	9	20
Locking Joints	0	2
	136	136

The data show that in general the new arms permitted a greater range of forearm flexion than did the preprogram arms, partly no doubt because of an increased use of step-up joints in the new prostheses and partly because of improved socket shaping to avoid restriction of flexion through crowding of flesh at the brim of the socket.

Before the advent of the Upper-Extremity Field Studies, use of flexible elbow joints had



been reserved almost entirely for patients with wrist disarticulations or long below-elbow stumps. Of all the amputees in the group investigated, only 17 had had flexible joints in their preprogram arms, and of these only one had a stump shorter than 6½ inches. Moreover, the available stump rotation was rather good, only one having less than 20 deg. of pronation-supination. Experience indicated that even still shorter stumps might retain slight but useful rotation and that patient comfort might be increased and clothing damage decreased with use of flexible hinges. Consequently, during the program many stumps within the group of 136 amputees (74 arms) were fitted with flexible joints even though the rotation possibilities were knowingly limited (22 cases with residual stump rotation of less than 20 deg., 13 patients with stumps shorter than 6½ in.).

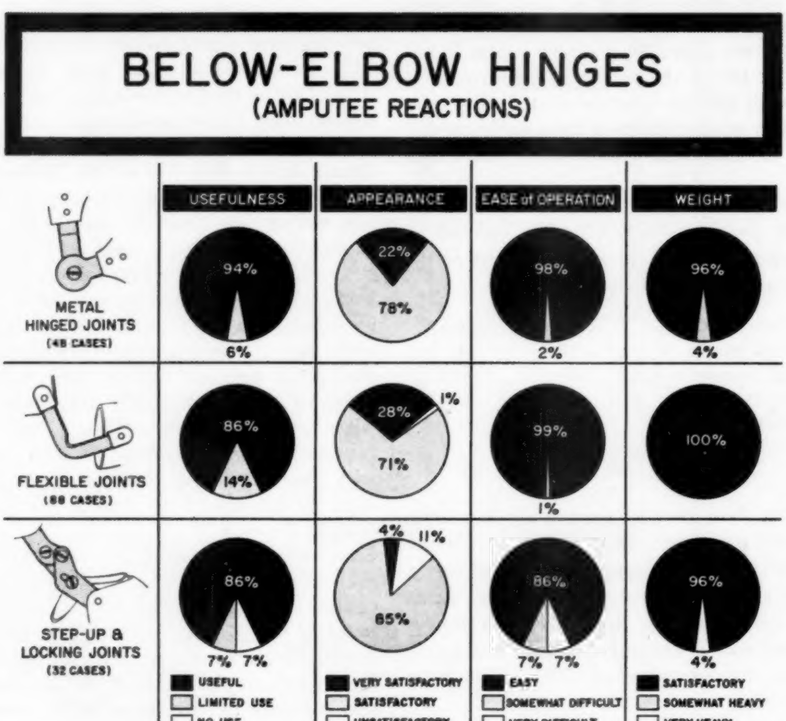
As expected, the average rotation range for the entire group with the new prostheses decreased as compared with the average rotation range of the 17 who had been provided with flexible hinges on their old arms. But it must be pointed out that many more amputees now had not only the facility of active pronation-supination but also the greater comfort and reduced clothing damage inherent in the use

of flexible joints. The 16 amputees who used flexible hinges on both old and new arms exhibited the same range of pronation-supination with the two prostheses.

The reactions of the below-elbow subjects to the various elbow joints evaluated during the study were in general very positive in the areas of usefulness, ease of operation, and weight but a great deal poorer in the area of appearance. Although the step-up and stump-actuated joints were unacceptable to a few amputees, negative generalizations are impossible because the size of the sample was too limited (24 step-up joints, 7 locking joints). And indeed these components must be widely acceptable, judging from the overwhelming percentages of positive responses. The negative comments made by wearers of step-up joints indicate an inability to stabilize the forearm sufficiently to obtain effective use of the terminal device. The development of locking step-up joints has been suggested as a means of stabilizing the prosthetic forearm for amputees with short or very short stumps.

The principal findings with regard to elbow joints for below-elbow prostheses center around a shift toward increased use of flexible hinges and a corresponding decrease in the number of rigid joints used.[6] Of special interest is the finding that stumps shorter than 6½ in. should also be considered for flexible elbow joints. Although the shorter stumps can be expected to provide only minimal pronation-supination, even slight gains in rotation are important for hand and hook positioning. There was no reported instance of socket instability on the

[6] See ARTIFICIAL LIMBS, Spring 1958, p. 77.



shorter stumps fitted with flexible joints on program arms, and the gains in patient comfort and in reduction of clothing damage lead to the conclusion that use of any joint other than flexible should be advocated only after serious consideration of the specific needs of the individual patient. Although the sample using step-up or locking joints was small, and although it is apparent that the joints were generally satisfactory, development of a step-up joint capable of locking the prosthesis in flexion seems quite desirable, since stabilization of the forearm for effective terminal-device operation or for lifting objects appeared to be difficult with the step-up joints used both before and during the study.

Elbow Joints for Above-Elbow and Shoulder-Disarticulation Prostheses

Positioning of the prosthetic forearm and terminal device of a modern above-elbow or shoulder-disarticulation prosthesis in the flexion-extension plane requires that the elbow be unlocked. Locking of the elbow permits control-cable forces to by-pass the forearm lift and to act upon the terminal device.[7] Rotation of the prosthesis about the humeral axis to facilitate mediolateral positioning of the forearm is accomplished by means of a turntable incorporated in the elbow and controlled by a friction element which resists free movement (*5*).

In general, about 2 lb. of force and half an inch of cable travel are needed to lock present mechanical elbows, about 5 lb. to unlock. But the exact figures vary slightly from elbow to elbow and from manufacturer to manufacturer. Program arms fitted during the early phases of the study were built around Sierra Model C elbows (*4,5*), which had unlocking forces (6.3 lb.) and excursion requirements (9/16 in.) slightly higher than those of the Hosmer E-400 units (4.0 lb. and 1/2 in.), which in turn became available to the clinics later in the study and which were identical in operating principle. Besides this, the Hosmer E-400 (*4,5*) was at the time a new component, clinics were therefore particularly interested in its application, and consequently it was prescribed almost routinely during the latter part of the program. Of the 170 internal elbows fitted and evaluated during the study, 110 were Sierra Model C's, 42 were Hosmer E-400's, and 18 were Hosmer E-300's (an earlier elbow incorporating a locking mechanism of quite different design, now discontinued). External elbow locks (*1*), intended for amputees with long humeral stumps or with elbow disarticulations, were used in 11 cases.

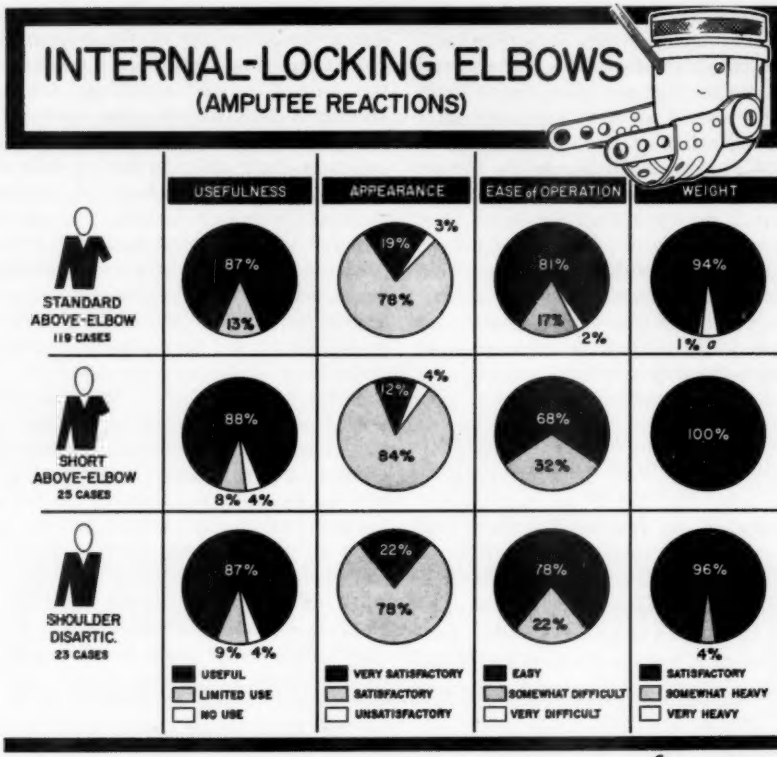
Above-elbow and elbow-disarticulation amputees achieve elbow locking and unlocking by a combined extension-abduction of the humeral stump, a motion which exerts pull upon a control cable attached between the elbow and the shoulder harness (*11,12*). Alternate pulls on the elbow-lock control cable result in locking and unlocking or vice versa. Shoulder-disarticulation amputees usually control the elbow lock by elevating the shoulder on the side of the amputation, thus exerting pull on a control cable attached between elbow lock and waistband (*10*).

All of the elbow-disarticulation, above-elbow, and shoulder-disarticulation prostheses provided in the program were equipped with locking elbows of the alternating type. Of the 181 cases (170 internal locking, 11 external locking) available for study, 76 had had prior experience with prostheses incorporating the older manual locks, and 18 had worn arms without locking elbows. Fifty-two had previously used alternating elbows of the type used in the program arms. In 35 cases, either the patient had not previously worn an arm or else the type of elbow was unknown.

INTERNAL-LOCKING ELBOWS

The data show that a considerable number (36 out of 101) of the preprogram arms provided little or no initial elbow flexion, owing chiefly, no doubt, to fabrication technique and workmanship rather than to the nature of the elbow units themselves. Program arms tended to group around the standard of 10–15 deg. of initial flexion, a feature that tends to make initiation of forearm lift less difficult. Moreover, forearm flexion was restricted in the old arms, less than a third of them being capable mechanically of approaching 135 deg. of flexion. In general, program arms could be flexed to

[7] "Dual control." See Pursley (*10*) or Taylor (*11*).



[a] *Not responding, 5%*

much greater extent, almost two thirds of the subjects reaching or surpassing 135 deg.

As for other deficiencies in the new arms, 35 cases exhibited serious impairment of elbow-lock operation, primarily because of harnessing inadequacies. A considerably larger number of prostheses showed less than optimal elbow function, mostly because of poor arrangement of the elbow control cable and the front support strap. In 12 cases, malfunction of the elbow mechanism was apparent, and 37 of the new prostheses required adjustment for insufficient initial elbow flexion. Thirteen arms required attention to correct friction characteristics in the elbow turntables.

Generally, then, more careful attention to adjustments and to harnessing detail for elbow-lock operation was obviously required. Direct amputee reactions to the cable-controlled, internally locking elbows were quite favorable, only 4 of the 170 wearers experiencing negative feelings when all aspects of elbow use were considered. Of the few negative comments made (25), the majority related to lack of dependability in elbow operation, probably because of such factors as careless harnessing or inadequate training in the required operational pattern. As might have been expected, the cases with the shorter stumps found operation of the lock more difficult than did those with the longer stumps. Except where the fitting of the short-above-elbow patient was expertly done, the shoulder-disarticulation cases had less difficulty in elbow locking and unlocking by means of shoulder elevation than did the short-above-elbow cases using the same control motion.

EXTERNAL-LOCKING ELBOWS

External-locking elbow joints are sometimes used for elbow disarticulations and for very long above-elbow cases (*1*). Although in the study 11 elbow-disarticulation amputees were fitted with external joints, only 8 had had experience with internal-locking elbows on their old arms. From the viewpoint of usefulness, they favored the internal mechanism slightly, perhaps because of the rotation turntable and because of the greater number of available locking positions in the internal elbows. As for appearance, the arms fabricated with outside-locking elbows seemed to be more acceptable than those constructed with internal units because, while the outside-locking units protrude on the medial aspect of the arm, internal units may be fitted to elbow disarticulations and to very long above-elbow cases only by lowering the elbow center abnormally.

Ease of operation gave rise to some differences in amputee reactions toward internal as compared with external elbows. Since the forces and control motions are essentially identical in the two types, the discrepancies probably relate more to the nature of the harnessing or to the skill of the patient than to the particular characteristics of the elbows themselves.

As one might have anticipated, amputee reactions to weight favored the outside-locking units, which are somewhat lighter than the internal elbows.

SUMMARY

To summarize, only 29 percent of the 181 amputees studied were known to have worn on their preprogram arms locking elbows of the alternating type. In the studies, all unilateral above-elbow patients were fitted with the more modern locking units, thus freeing the normal arm from the responsibility of operating a manual lock for the amputated side. Program arms had greater ranges of forearm flexion and were adjusted to provide greater initial flexion so as to make it easier for the patient to lift the forearm. But elbow-lock operation with the new arms was often impaired by poor harnessing arrangements that required correction. While in general the amputees were quite favorably disposed toward the cable-controlled, locking elbows, infrequent negative complaints of lack of dependability related to inadequacies in harnessing and to poor operational patterns on the part of some wearers. A limited number of amputees fitted with external-locking joints provided sufficient positive evidence to ensure the future of these components in the array of items available for long-above-elbow or elbow-disarticulation patients.

Harnessing

If the upper-extremity prosthesis is to be of functional use to the amputee, two basic needs must be met. A suitable attachment of the prosthesis to the body must be made, and power must be provided for operating and controlling the limb. Although the socket is made to conform to the stump, it tends to become displaced, especially during lifting. The prosthesis is therefore suspended from the shoulder by means of a harness which keeps the socket in close contact with the stump and resists any tendency for the prosthesis to shift out of position. Usually the same harness serves as the force-transmitting medium between body sources of power and the cable system of the prosthesis (*10,12*). For both above- and below-elbow amputees, two basic types of harness are in common use today—the figure-eight harness and the chest-strap harness (*10*). Commonly, the chest-strap design is applied in the shoulder-disarticulation case too (*10*).

Of all artificial arms, the unilateral below-elbow prosthesis is perhaps the simplest to suspend and to power. In the figure-eight method, suspension is obtained by a loop of 1-in. fabric tape passing under the axilla on the sound side and over the shoulder on the amputated side, the front end of the tape being attached to a biceps cuff (which in turn supports the elbow joints connecting to the prosthetic forearm), the other end (the back) to the control cable for the terminal device. Forward rotation of the arm upon the shoulder on the amputated side causes forces to be applied to the cable and gives the excursion necessary to operate the hook or hand. In the chest-strap method, suspension of the biceps cuff is achieved through use of adjustable leather or fabric straps attached to the anterior and posterior aspects of a leather shoulder saddle, and the control cable is attached to

an adjustable fabric tape sewn to the chest strap in the region of the seventh cervical vertebra. Although the figure-eight type of harness is used almost universally for the unilateral below-elbow prosthesis, it is considered by some that the chest-strap type, with its broader weight distribution over the shoulder, is indicated for amputees anticipating extremely heavy-duty services or for those who cannot tolerate the axilla pressures typical of the figure-eight loop (*10*).

For the unilateral above-elbow prosthesis, the figure-eight and the chest-strap harnesses enjoy in general a more equal popularity. Program arms tended strongly, however, toward the simpler figure eight, in which the fabric tape loops over the sound shoulder, under the axilla on the sound side, and then over the shoulder on the amputated side (*10*). It is generally conceded that the above-elbow chest-strap harness, which uses a leather or fabric saddle to reduce the unit pressure on the shoulder, is preferred whenever the patient anticipates activities involving heavy lifting or when he cannot tolerate the axilla pressure characteristic of the figure-eight harness (*10*).

For the unilateral shoulder-disarticulation or forequarter amputation, the most common harness in use today is that of the chest-strap type, elbow locking and unlocking being achieved by elevation of the shoulder on the amputated side. A fabric tape extends from the elbow-lock control cable and attaches to another surrounding the waist. Scapular abduction gives power and excursion for forearm lift or, when the elbow is locked, for terminal-device operation (*10*).

In the evaluation studies, harnesses were individually prescribed according to type and made in accordance with the latest techniques. But because the harness is always a custom-made item fitted by the prosthetist according to the requirements of the individual patient, there were introduced a number of variables involving such intangibles as skill and judgment. Although in program prostheses each harness had to meet certain requirements designed to ensure proper suspension and adequate power and excursion, it was apparent almost from the beginning that serious harnessing problems existed. About 45 percent of all arms showed harness deficiencies at checkout. The above-elbow prostheses were notably troublesome, 375 harnessing faults showing up on the 303 arms going through checkout. The below-elbow prostheses, though considerably simpler, were also a source of difficulty, 150 harnessing faults being discerned on 361 below-elbow patients. The shoulder-disarticulation group of 53 patients had 39 harnessing faults. Tables 1, 2, and 3 reflect the types of harnessing faults found at clinical checkout of the program arms.

It should be pointed out that the prostheses were rated at checkout according to criteria evolving from material presented at the prosthetics courses offered as part of the program. Accordingly, any deviations from the accepted harnessing practices taught in the courses were considered "faults." But it was recognized that arm harnessing is an individualized procedure and that therefore certain faults might be less critical than others depending upon the amount of deviation from the standard, the physique of the patient, his threshold of tolerance for discomfort, and other intangible considerations. Consequently, it should be made clear that recognition of a fault did not necessarily mean the prosthesis was unusable but, more often than not, that the limb simply was not operating at a peak level of performance and/or comfort. Fortunately, the problems encountered with the harnesses at checkout were markedly reduced as the prosthetists gained experience. Strict adherence to the checkout standards, along with increased understanding and skill, served to ensure that each arm wearer was ultimately harnessed so that he could use the prosthesis in a functional manner. After checkout (and prosthetic corrections, when indicated), the amputees embarked upon a long-term period of wearing the new prosthesis.

Amputee reactions to the new arm harnesses were checked with regard to comfort, appearance, and fit as these matters affected the function of the prosthesis. Generally, the wearers' reactions were quite favorable, and it was apparent that the subjects generally had a higher regard for the new harnesses than they had for the old (Table 4). Although program harnesses scored highly with all

Table 1

HARNESS FAULTS RELATING PRIMARILY TO FUNCTION

(Forearm Lift, Elbow Lock, Prehension)

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Control attachment strap not at mid-scapular level	28	78	3	109
Harness cross too far toward amputated side	31	32		63
Front support strap, elastic strap, elbow-lock lanyard not in delto-pectoral triangle	13	35	1	49
Harness inadequate (not further identified)	1	25	5	31
Bilateral cross not centered on back and/or too high on back	3	25		28
Difficulty in elbow-lock operation		22	1	23
Harness control too far toward sound side	10	5		15
Additional, nonprescribed straps	1	14		15
Control attachment strap too short	8	4		12
Insufficient control-cable excursion		2	7	9
Nonstandard materials used	4	4		8
Improperly located harness cross (not further identified)	3	4		7
Harness not as prescribed		2	3	5
Figure-8 harness improperly laid up, restricts range of motion		5		5
Harness stretched	1	3		4
Elastic suspensor missing		2	1	3
Chest strap improperly placed, restricts range of motion		1	1	2
Totals	103	263	22	388

amputee groups, the above-elbow amputees consistently rated their harnesses slightly lower than did the below-elbow or shoulder-disarticulation groups, probably because the above-elbow figure-eight harness is more complex and in comparison with below-elbow harnesses somewhat more snug-fitting.

Interviews with the amputees disclosed that most participants who had worn prostheses prior to the studies felt that the new harnesses

Table 2

HARNESS FAULTS RELATING PRIMARILY TO SOCKET ATTACHMENT AND STABILITY OF PROSTHESIS

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Lateral support straps improperly located for socket stability		31		31
Harness does not stabilize socket (not otherwise identified)		11	4	15
Elastic suspensor misplaced so as to cause socket rotation		1		1
Totals	0	43	4	47

Table 3

HARNESS FAULTS RELATING PRIMARILY TO COMFORT AND APPEARANCE

Fault	No. of Occurrences			
	Below-Elbow (361 cases)	Above-Elbow (303 cases)	Shoulder Disarticulation (53 cases)	Total (717 cases)
Discomfort at axilla	14	27	1	42
Inverted Y-strap improperly sized	22			22
Discomfort, other than at axilla (not further identified)	2	13	1	16
Buckles improperly attached	2	11	1	14
Harness-tape ends not sealed	3	7	2	12
Discomfort, lateral suspensor strap irritates neck		7		7
Discomfort, front support strap too high on neck	4	1		5
Chest strap of improper width		2	3	5
Discomfort, chest-strap tightness			2	2
Shoulder saddle bulges		1	1	2
Waist strap (elbow lock) improperly sized			2	2
Totals	47	69	13	129

were much better than the old ones. Particular comments evidenced satisfaction with reduction in amount of harness needed to obtain satisfactory prosthetic function with the new arms. Some wearers commented upon possible areas of improvement, a response which almost always involved the desire to be burdened with no more harness than necessary to control the arm. A number of subjects indicated discomfort at the axilla, and problems relating to shift of the harness out of place were not uncommon. Although difficulty in operating the elbow lock was corrected in most cases, some wearers felt that other means should be sought for control of elbow lock.

POWER-TRANSMISSION SYSTEMS

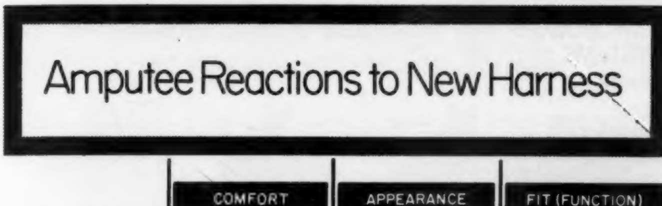
To achieve functional use of a prosthesis, the amputee must be able to avail himself of residual sources of body power. Flexion, extension, and abduction of the arm, extension of the forearm, shoulder elevation, scapular abduction, and chest expansion are the most common power sources harnessed by the prosthetist to provide movement of the artificial arm (*10, 11, 12*). Transmission of the forces thus generated is accomplished by the use of Bowden cables connecting the points of force generation (harness components) and the points of force application (forearm or terminal device). In the below-elbow prosthesis, forward movement of the shoulder on the sound side, flexion of the arm on the amputated side, singly or in combination, exerts against the

Table 4

AMPUTEE PREFERENCE IN HARNESS

(No. of Occurrences)

Harness Type	Amputee Type	Preference		
		Prefer Old	No Preference	Prefer New
Figure-8	Below-Elbow	13	25	85
	Above-Elbow	20	8	73
Chest-Strap	Below-Elbow	—	3	—
	Above-Elbow	—	8	—
Totals		33	44	171



harness system a force that is transmitted for operation of the terminal device, the forearm being lifted by the stump. Above-elbow and shoulder prostheses utilize the same type of power-transmission system, except that with arms of this type the cable is used also to lift the prosthetic forearm whenever the elbow is unlocked (dual control).

Prior to the Upper-Extremity Field Studies, many arm amputees had been using Bowden cable for power transmission. Others used steel cable without housing, nylon cord, leather or rawhide thongs, and other miscellany, as shown in Table 5. But *all* program arms were equipped with Bowden cable and subjected to checkout procedures to ensure that minimum standards of power-transmission efficiency (below-elbow prostheses, 70 percent; above-elbow and shoulder-disarticulation prostheses, 50 percent) were met. When checked, the program arms showed for every amputation level substantial increases in efficiency over the standards shown by the power-transmission systems of the corresponding old prostheses. Indeed, the new arms exceeded the minimum efficiency standards with such regularity that raising of the standards is now indicated.

Full opening and closing of the terminal device was possible for an increased number of amputees through use of the new arms. When function of the terminal device was tested at each of four operating positions (at full extension, at 90 deg. of flexion, at waist, and at mouth), the results showed a marked increase in opening range for each amputee type at all four positions. Doubtless this improvement was due to the use

Table 5

Power-Transmission Systems Encountered

(285 Old Prostheses)

Prosthesis Type	Power-Transmission System				
	Bowden Cable	Steel Cable, No Housing	Leather Thong	Nylon Cord	Miscellaneous (Shoelace, String, etc.)
Below-Elbow	83	11	30	14	4
Above-Elbow	80	10	18	12	10
Shoulder Disarticulation	7	1	3	1	1

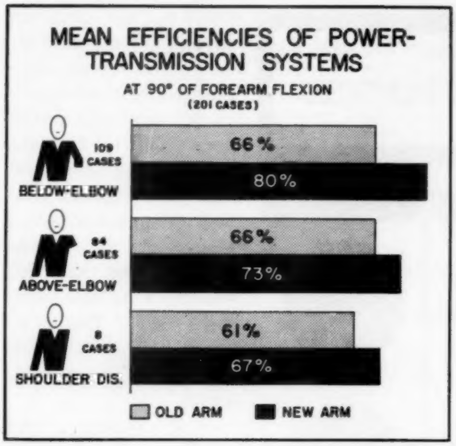


Table 6

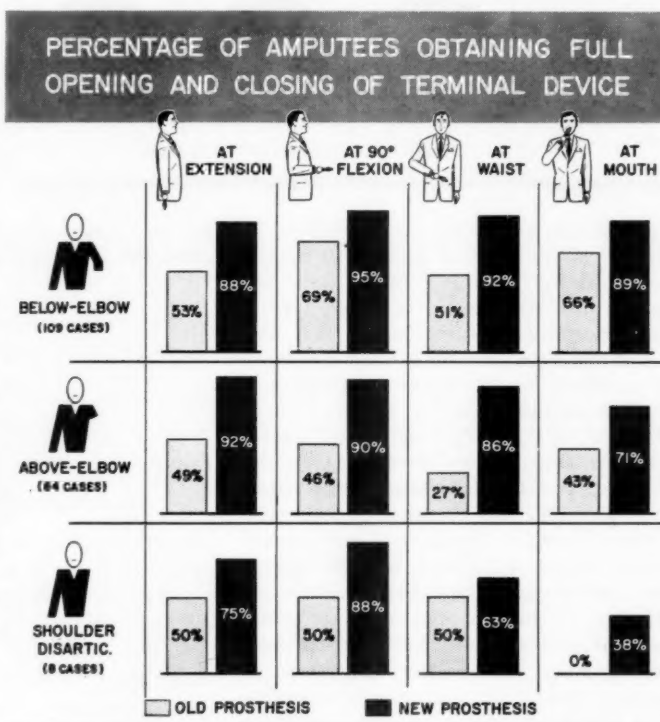
DEFICIENCIES IN POWER-TRANSMISSION SYSTEMS
(Based on Initial Checkout of 790 New Prostheses)

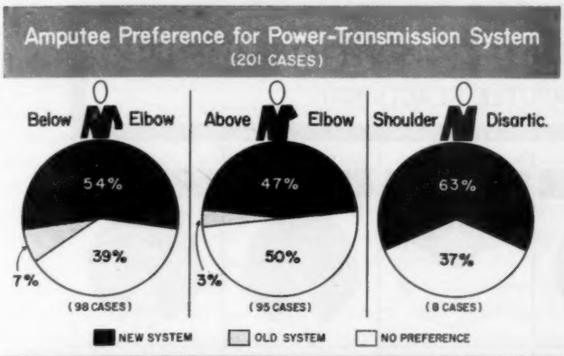
Prosthesis Type	Deficiency			
	Cable and/or Cable Housing of Improper Length	Retainers Improperly Aligned	Poor Solder Joints	Faultless
Below-Elbow	64	77	49	231
Above-Elbow	102	86	67	148
Shoulder Disarticulation	21	16	8	27

of better harness and better-fitting sockets, with better transmission of force and excursion through the cabling system, if not to application of the voluntary-closing terminal devices, which inherently use less excursion than do the voluntary-opening hooks that predominated in the old prostheses.

Initial checkout of all patients provided with program arms revealed some problems in application of the Bowden cable (Table 6). Faulty placement of retainers, improper cable lengths, and poor soldering of connections were the main sources of trouble. Of course some of the arms had more than one fault, whereas about half of the 790 arms fitted and checked out in the study had no faults at all in the transmission system.

Those in the study who had used power-transmission systems in both old and new arms (285) generally found the Bowden-cable system easy to use, acceptable in noise level and in appearance, kind to clothing, and free of





excessive maintenance requirements. Of these amputees, 201 responded to questions intended to elicit preference either for their old or for their new cable systems. Only 10 of the 201 in the group preferred their old power-transmission systems, 103 preferred the new. Yet 88 had no preference, which indicates that a significant number of preprogram arms had the advantage of an adequate power-transmission system.

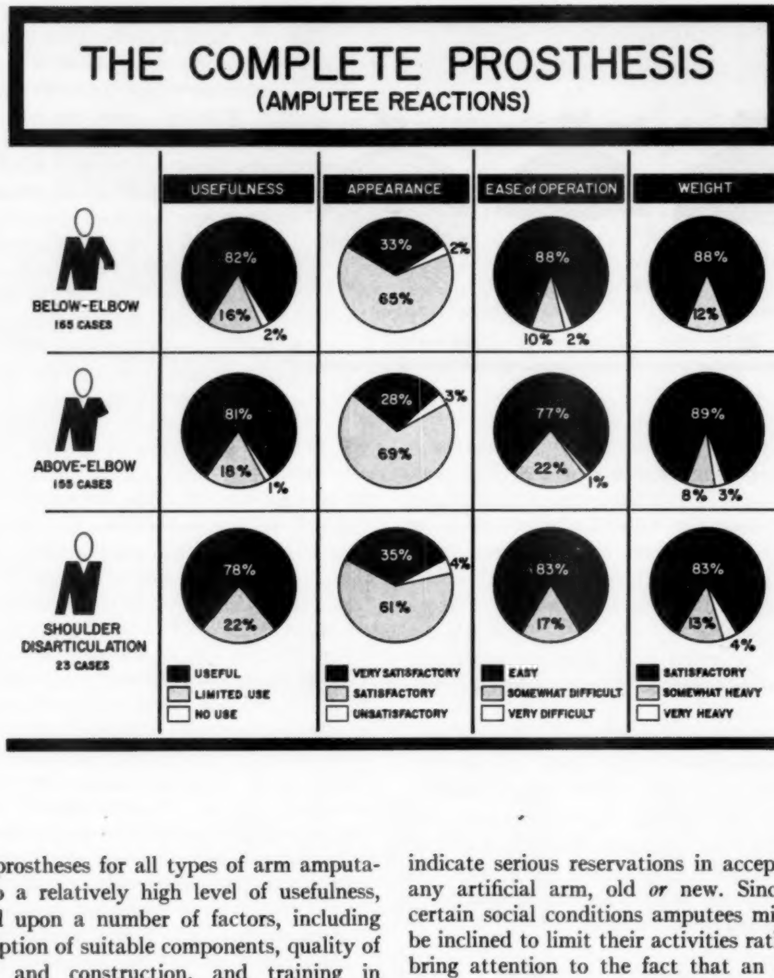
Suggestions for improvement indicated that the amputees would have liked to have seen the cables concealed within the prosthesis, although the existing appearance was not considered unsatisfactory. Easier and quieter operation might also constitute an improvement, although here again there appears to have been no major criticism.

The Complete Prosthesis

Thus far we have considered only the individual elements of the prosthesis. A matter of equal importance, however, is the consideration of the prosthetic appliance in its entirety and of the effects of clinical treatment and training with the prosthesis. Although the data presented here concern the below-elbow, above-elbow, and shoulder-disarticulation cases only, findings from the 10 bilateral amputees who were available for evaluation may also be considered indicative of probable trends. The responses of the small bilateral group, consistently positive toward the new program arms, were substantially in agreement with the responses from the other amputees.

Although most wearers considered their new arms to be useful, the desire for further improvement was reflected in the significant percentage of wearers who considered the arms to be of limited use only. When the amputees compared the general usefulness of the old prostheses with the general usefulness of the new arms, the new arm was preferred. The greatest improvement showed up in the shoulder-disarticulation and above-elbow groups. When all amputation levels were considered together, only 59 percent of the wearers felt that the old prosthesis was "useful." With the new arms, the figure went up to 79 percent. While nearly 5 percent of the wearers felt the old arm to be of no use, less than 1 percent reacted in this manner to the new arms.

Perhaps the most meaningful gains in function were made in the area of harnessing and in routine use of locking elbow joints for above-elbow and shoulder-disarticulation cases. Although harnessing problems existed initially with program arms, the checkout procedures brought the difficulties to light so that suitable improvements could be made. Certainly arm harnessing was a major problem prior to the Field Studies also, as indicated by the fact that the new harnesses were preferred over the old by a ratio of five to one (Table 4). Locking elbow units, which stabilize the forearm and terminal device for above-elbow and shoulder amputees, are obviously superior to nonlocking elbows from a functional standpoint. For without elbow lock, prehension is handicapped, pushing and pulling with flexed elbow are seriously impaired, and carrying with flexed elbow (as in carrying a coat over the arm) is so difficult as to be impractical. Although manual elbow-locking mechanisms are effective, the newer elbows, operated through the harness system, free the sound hand for more important services. But it must be remembered that all these gains, which now



bring prostheses for all types of arm amputation to a relatively high level of usefulness, depend upon a number of factors, including prescription of suitable components, quality of design and construction, and training in prosthesis use, all of which doubtless contributed to the positive attitudes displayed by the test wearers.

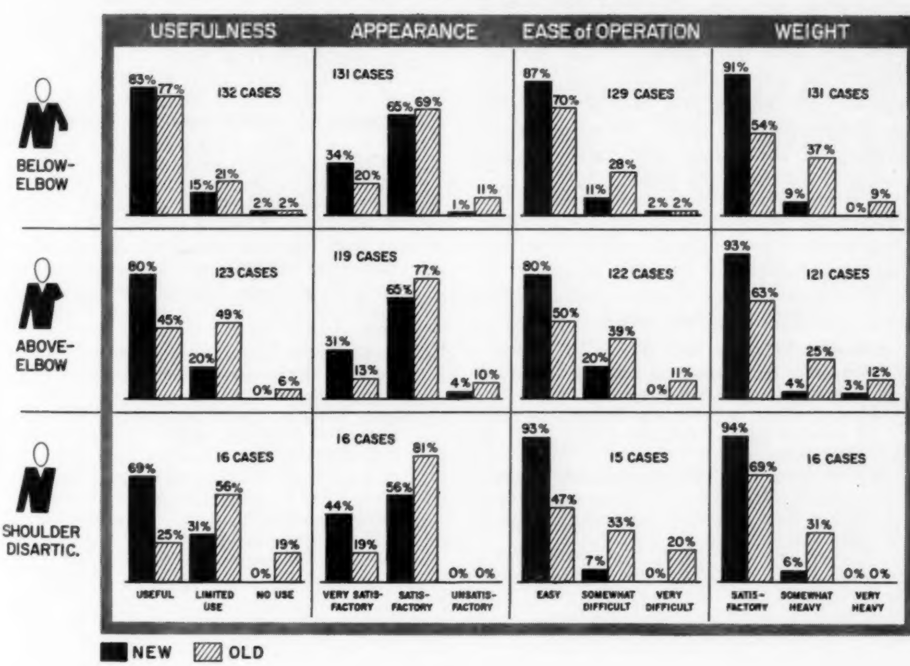
The appearance of the new plastic-laminate arms was accepted in a perfunctory way only, most of the arms being considered "satisfactory." When 266 amputee responses were compared (appearance of new arm *vs.* that of old arm), it was evident that positive changes in reaction had taken place. In general the amputees favored the newer arms. It is in the area of appearance alone that the responses indicate serious reservations in acceptance of any artificial arm, old *or* new. Since under certain social conditions amputees might well be inclined to limit their activities rather than bring attention to the fact that an artificial arm is being worn, sensitivity toward appearance is extremely important. Even the best arm prostheses available today fall far short of being cosmetically adequate and cannot hope really to satisfy either wearers or observers.

Ease of operation of the new prostheses apparently left something to be desired for a substantial number of the amputees, especially those of the above-elbow and shoulder-disarticulation types. Simpler elbow-lock operation and reduction in the difficulties of terminal-device positioning (perhaps by pro-

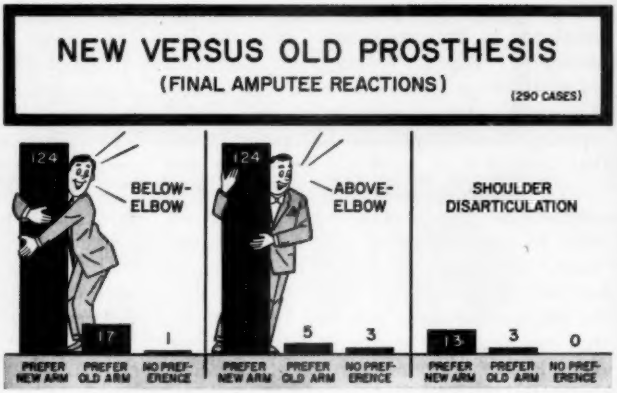
viding more mobility at the wrist) were mentioned as important areas requiring improvement. When the amputees compared old and new prostheses with respect to ease of operation, the new arms nevertheless proved superior. Many amputees (59 percent) felt that operation of their old prostheses was "easy." But when later they were asked to comment on the ease of operation of their new arms, 84 percent replied that operation was "easy." Slightly over 7 percent of the wearers felt that operation was "very difficult" with the old arms, whereas less than 1 percent felt that way about the new arms. Although again these important gains were most prevalent among the shoulder-disarticulation and above-elbow cases, significant improvements were noticed among the below-elbow amputees also.

Although to date very little attention has been given to study of its significance, the weight of the prosthesis has always occasioned a great deal of interest. Generally speaking, the practice has been to keep weight at a minimum, since amputee weight tolerance has not as yet been determined specifically. The data indicate that the below-elbow arms furnished in the program were slightly lighter than the corresponding preprogram arms (1.8 lb. compared with 2.1 lb.). Above-elbow prostheses weighed an average of 2¾ lb., there being no significant differences between the old and the new. The average weight of the new shoulder-disarticulation arms was about 3½ lb., about ½ lb. heavier than preprogram types. Amputees at all levels generally felt that the total weight of the new prosthesis was satisfactory, although

NEW VERSUS OLD PROSTHESIS
(AMPUTEE COMPARISONS)



there were some indications that further weight reduction would be welcomed. About 7 percent of the subjects felt that the prostheses were somewhat heavy, less than 2 percent that they were very heavy. But 33 percent of the wearers considered the new prostheses *more* acceptable in terms of weight than the old arms, even though only slight differences in actual weight were noted. Such reactions are thought to be related to increased function, improved comfort, better fit, and/or improved weight distribution in the new arms.



When comparisons were made between amputee reactions to the old and to the new arms, the data for all levels of amputation clearly favored the newer, program-type, plastic-laminate prostheses. Such endorsement by wearers reflects not only the superior construction and the improved mechanical components incorporated into the newer prostheses but also the values of the patient-management procedures advocated by the program—prescription of carefully selected arm components, checkout to ensure basic adequacy of the fitting, and finally proper training in the use of the prosthesis.

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Studies of the Upper-Extremity Amputee

VI. Prosthetic Usefulness and Wearer Performance

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SYSTEMATIC research in limb prosthetics has, during the past decade, produced not only better prostheses but also improved techniques for their application. Similarly, programs of prosthetics education have provided a new generation of physicians, prosthetists, therapists, and associated professional personnel with a greater appreciation of the amputee's physical and emotional needs and a greater understanding of how best to meet them. But ultimately research and education in the fitting of artificial limbs have real worth only to the extent that the individual amputee can accept and utilize the prosthesis provided him.

The degree of acceptance and utilization is governed ultimately by the single consideration: *Of what value is the prosthesis to the amputee?* While the wearer himself must provide the essential elements of this valuation, his feelings and attitudes about other matters can significantly affect his opinions and judgments about the worth of his prosthesis. Accordingly, data which included both subjective amputee reactions and more objective ratings and judgments of independent observers were collected. Properly analyzed, these data provide a firm assessment of recent achievements in arm prostheses as well as some measure of the effectiveness of the techniques now recommended for the management of arm amputees.

The classification, analysis, and interpretation of the more subjective portions of the data (those collected by interrogation of amputee subjects) make up Part 1 of this two-part discussion. Presentation and support of the more objective material (that obtained by tests and observation) constitute Part 2. All of the data reported were recorded on the special forms illustrated in Appendices IIIB and IIIC of Section I of this series (ARTIFICIAL LIMBS, Spring 1958, pp. 32 through 39).

The opinions and statements reported in Part 1 and the test results and observations presented in Part 2 relate to the meaning and the value of program prostheses in various tasks normally encountered in everyday life. As a perceptive reader will note, the term "activities of daily living" is used throughout this article to denote that specific context and is not meant to be synonymous with the term "ADL," which through increasing currency has become part of the professional jargon of physical and occupational therapy. As used here, it encompasses a broader range of activities than it does when generally used in the treatment of human disability. Generally ADL is limited to tasks relating to personal independence and self-care in the home; in our context, recreational and vocational activities are included.

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Part 1

Amputee Opinions Concerning Utility of Arm Prostheses in Activities of Daily Living

In general, the prosthesis that will be most valuable to the arm amputee will be the one with which he can perform, most efficiently and with the least effort and discomfort, the greatest number of useful activities ordinarily performed with the normal upper extremity. Thus an evaluation of an arm prosthesis can be based upon the *usefulness* of a prosthesis to the patient as indicated by his need for it in performing daily activities, the *activity level* of the patient with respect to the number of activities which he performs with his arm, the *ease* with which he uses the prosthesis, and the *frequency* with which he uses it for the performance of activities which are important to him.

To obtain amputee reactions concerning the general utility of arm prostheses, the participating subjects were intensively interviewed, and the essential data were recorded on two sets of questionnaires. One set was used to record amputees' opinions of the usefulness of their arms in activities of daily living, the activity level as regards the number of different activities they performed, and the degree of ease or difficulty with which they were able to use their prostheses. The second set of questionnaires was used to collect data concerning the use of prostheses in 20 selected bimanual activities, specifically the frequency with which these activities were performed and the importance to the amputee of being able to perform these activities. With certain minor exceptions, the interrogation was conducted with respect both to the old prosthesis (Evaluation I) and to the new (Evaluation II). The time lapse between the two interviews varied for individual amputees; it was never less than six months for any, as much as 18 months for a few, and approximately 12 months for the average case.

Usefulness, Activity Level, and Ease of Use in Activities of Daily Living

In view of the complexities of everyday human activities, almost any attempt to study the circumstances affecting prosthetic utilization is difficult. As a practical approach to the problem, however, the subjects were queried in a pattern designed to elicit their opinions concerning the value of both their old and new prostheses in the key activity areas of eating, dressing, work, social and recreational functions, and home tasks.[3] To determine general usefulness, the amputees were asked to rate their prostheses (first the old and then the new) as essential, very useful, of limited use, of no use, or as a hindrance, the purpose being to establish the amputees' own valuations of their prostheses in performing activities in the five activity areas. Secondly, the subjects rendered their own estimates as to the relative number of activities performed with old and with new prostheses, again with respect to the five key areas of activity. Finally, the subjects were asked to estimate the relative ease with which their old and new prostheses could be used in each of the same five areas.

The questionnaires regarding usefulness, number of activities performed, and ease of performance with both old and new prostheses were applied to all available types of upper-extremity amputees, unilateral and bilateral. Because the problems of the bilateral arm amputee differ from those of the unilateral, and because the number of available bilateral cases was too small to have statistical significance, the results for 349 unilateral subjects are treated first, those for the 10 bilaterals in a separate section.

Unilateral Subjects

Among unilateral arm amputees especially, the level of use to which an arm prosthesis is put is determined to a considerable extent by

[3] The five kinds of tasks selected were considered as encompassing the major undertakings in which an arm amputee *might* use a prosthesis in the course of daily living.

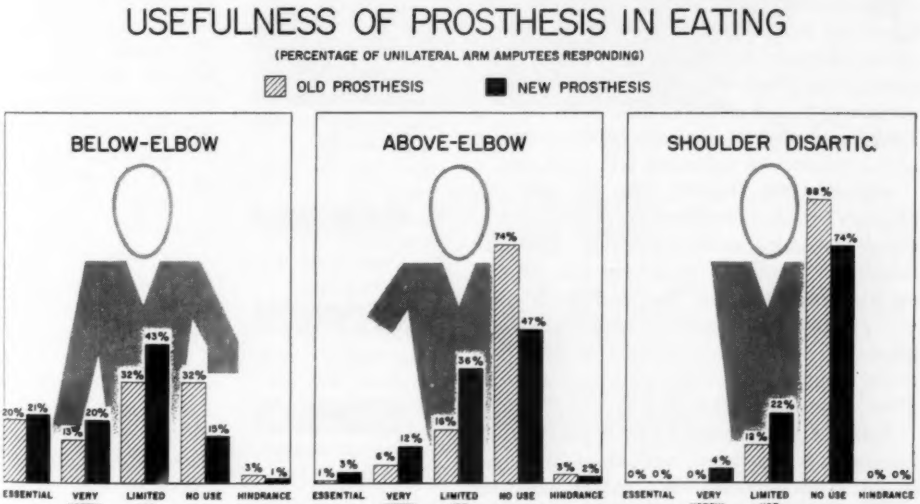
the ease and convenience of performance with the prosthesis as compared with the ease and convenience of performance without it or as compared with the ease and convenience of not performing at all. If a particular activity is too difficult or too time-consuming for a given unilateral arm amputee to perform with his prosthesis, he will either avoid it completely or else find some other way of getting it done. If he elects to accomplish the activity without using the prosthesis, he may do so in any of several ways:

1. He may use the remaining sound hand, with or without assistance from other parts of the residual anatomy or from external objects. Unilateral arm amputees commonly perform with one hand many activities which under normal circumstances would be bimanual (*e.g.*, tying necktie or shoelaces).
2. He may use special devices and techniques (*e.g.*, various tools intended for one-handed performance of tasks ordinarily bimanual), again with or without assistance from some other available source.
3. He may prevail upon another person either to provide assistance or to perform the task for him more or less completely.

Although any one of these alternatives may serve the purpose of accomplishing essential activities, none of them suggests adequate restoration of loss, either in terms of true personal independence or in the sense of normal appearance. In addition, factors such as temperament, disposition, motivation, and habit patterns further influence the simple "ease-difficulty" premise of prosthetic utilization. Though the true state of affairs in any particular case is a highly complicated one, there can be little doubt that the inherent "usefulness" of the prosthesis is one of the prime factors in determining the number and kinds of purposes to which an artificial arm will be put. This first series of studies was therefore designed to discover the activities for which prostheses are used by amputees with unilateral arm loss at various levels and to delineate any changes in use patterns properly attributable to the new types of prostheses fitted during the NYU Field Studies.

Eating

Usefulness. As regards eating, unilateral below-elbow amputees generally thought well of their old prostheses, above-elbow subjects



had a considerably lower opinion of their arms, and shoulder-disarticulation amputees viewed their prostheses as being of relatively little value. In almost all cases, the amputee rated the new prosthesis more useful than the old in eating. For all types of amputees, there were fewer opinions that the prosthesis was of "no use" or "a hindrance" and a greater number of opinions that it was "very useful" or "essential." While this shift in opinion was characterized primarily by a considerable decrease in the proportion of unilateral amputees (of all types) who considered their prostheses of "no use" or "a hindrance," there was also an increase in the number of those considering the prosthesis "very useful" or "essential."

Of major significance is the fact that even with the newer arms the majority of unilateral amputees (58 percent of the below-elbow amputees, 83 percent of the above-elbow amputees, and 96 percent of the shoulder-disarticulation subjects) felt that the prosthesis was of limited use or no use in eating. Since only 41 percent of the below-elbow amputees, 15 percent of the above-elbow amputees, and 4 percent of the shoulder-disarticulation subjects considered their new prostheses essential or very useful in eating activities, it must be concluded that, although there was some increase in usefulness in the "program" prostheses, considerably greater improvement is necessary if the artificial arm is to have a significant influence upon the eating activities of the majority of unilateral arm amputees.

Activity Level. Reports from all unilateral amputee groups indicated that the number of eating activities increased for a significant number of amputees while very few subjects experienced a decrease. The increase in usage was greatest for shoulder-disarticulation amputees (45 percent), less marked for the below-elbow group (34 percent), and least for above-elbow amputees (28 percent).

Ease of Use. As might be expected from the foregoing, a significant number of amputees of all types reported that eating activities were easier with the new prosthesis than with the old, although the increase in facility for the below-elbow and above-elbow groups was less marked than for the shoulder-disarticulation amputees.

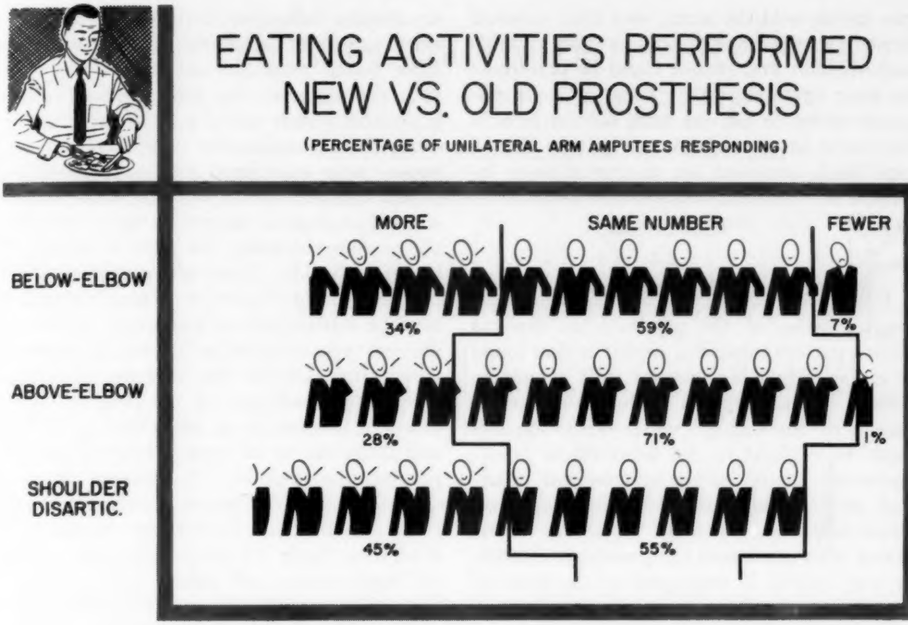
Specific Activities Performed. Table 1, based on responses from 168 below-elbow, 158 above-elbow, and 23 shoulder-disarticulation ampu-

Table 1

SPECIFIC EATING ACTIVITIES PERFORMED BY UNILATERAL ARM AMPUTEES USING A PROSTHESIS

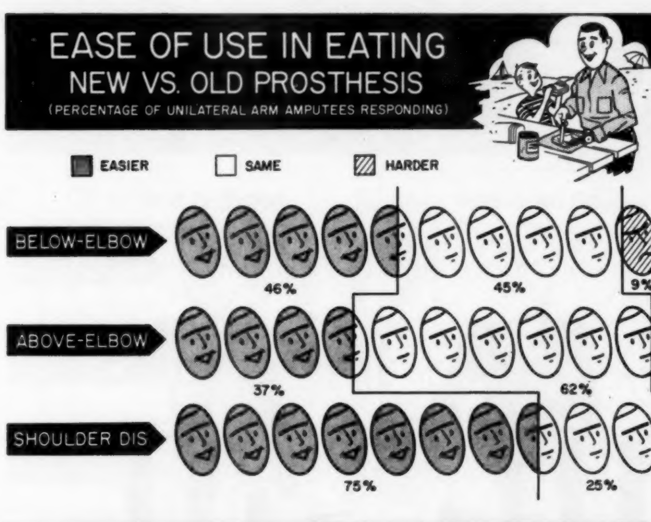
(Times Cited)

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Grasp knife or fork to cut meat	107	52	5
Grasp bread to butter	42	17	2
Grasp bottle or glass to hold	39	18	3
Grasp tray to carry	15	16	1
Grasp dishes to serve self	14	4	3
Grasp glass to bring to mouth	12	1	0
Hook pots and pot handles to take off stove	10	4	1
Grasp can to open	6	4	0
Grasp spoon to ladle food	5	0	0
Grasp fork to carve meat	5	3	0
Grasp orange to peel, egg to shell	4	3	0
Grasp soda bottle and bring to mouth	3	0	0
Grasp utensils to set table	3	2	0
Grasp saucer while drinking from cup	3	3	0
Grasp cabbages, tomatoes, to cut	3	2	0
Weight bread to butter	3	8	0
Support tray to carry	1	1	1



tees, presents a composite picture of the specific eating activities for which unilateral amputees of various amputation levels said they used their prostheses. Since the list of activities was compiled from amputees' responses to the unstructured request *List activities for which you use your [new] prosthesis*, and since in the experience of the authors arm amputees commonly use their prostheses more extensively than they can recall, it may be assumed to be minimal both with respect to number of activities and to incidence of performance.

The prime significance of these responses lies in their indication of use *potential* of the prosthesis. For example, the fact that in opening a soda bottle *some* below-elbow, above-elbow, and shoulder-disarticulation amputees



can and do hold the bottle with their terminal device suggests that this activity is not particularly difficult and that it could be performed by most amputees. Why, then, do some amputees prefer to use one hand only or to hold the bottle between the knees to take off the cap? Such questions are worthy of more intensive investigation than was possible in the NYU Field Studies.

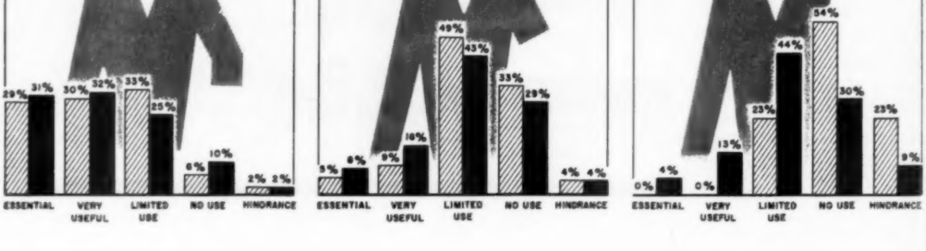
Dressing

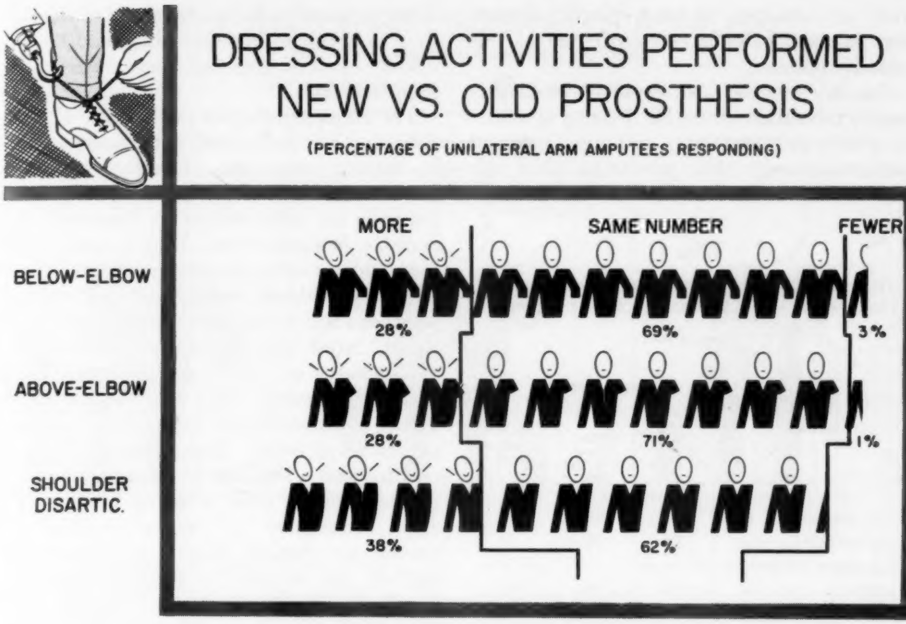
Usefulness. Amputees' opinions concerning the usefulness of the prosthesis in dressing show a pattern somewhat similar to that found in eating. There is a general shift of opinion toward the positive end of the scale, but the extent of the change varies with amputee type. It is slight in the below-elbow group, somewhat greater in the above-elbow group, and most marked among shoulder-disarticulation amputees. When the percentage of amputees who considered the prosthesis essential or very useful is employed as the basis of comparison, the data for new *vs.* old arm were: below-elbow, 63 percent *vs.* 59 percent; above-elbow, 24 percent *vs.* 14 percent; shoulder disarticulation, 17 percent *vs.* zero. Although because of the small number of subjects involved the data on the shoulder-disarticulation group must be interpreted cautiously, there are definite indications that a significant number of amputees considered the new prosthesis more useful than the one worn previously. It is also apparent that most groups consider a prosthesis ***more useful for dressing than for eating.*** The comparative percentages of amputees who considered the new prosthesis either essential or very useful were—below-elbow: dressing, 63 percent, eating 41 percent; above-elbow: dressing, 24 percent, eating 15 percent; shoulder disarticulation: dressing, 17 percent, eating 4 percent. These differences may be attributable to the larger number of discrete tasks involved in dressing as compared with eating. Despite the improved sentiment toward the usefulness of the program arms, however, a considerable proportion of unilateral amputees of all types (below-elbow, 37 percent; above-elbow, 76 percent; shoulder disarticulation, 83 percent) still considered these prostheses of limited use, no use, or a hindrance. Again it is obvious that much room for improvement still exists, particularly for the more severely handicapped above-elbow and shoulder-disarticulation groups.

Activity Level. An increase in the number of dressing activities performed with the prosthesis was reported by all amputee groups. The proportion of amputees indicating increased use of the prosthesis ranged from 28 percent

USEFULNESS OF PROSTHESIS IN DRESSING

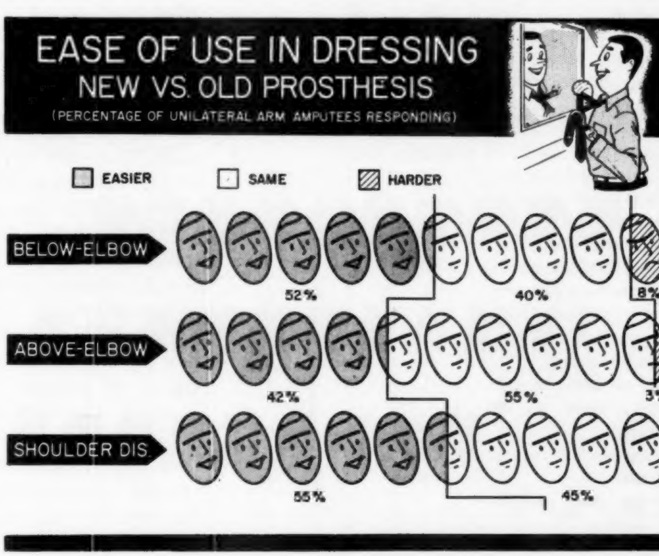
(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)





of the below-elbow category to 38 percent of the shoulder-disarticulation sample. An insignificant number reported decreased usage.

Ease of Use. Since extent of use is undoubtedly related to ease of use, it is not surprising to find that a high proportion of the amputees considered dressing activities easier to perform with their new prostheses than with their old. Easier operation was reported by 52 percent of the below-elbow, 42 percent of the above-elbow, and 55 percent of the shoulder-disarticulation subjects. Very few subjects at any amputation level reported greater difficulty of operation with the program prosthesis, although almost one in twelve below-elbow amputees fell into this category. The use of more complex terminal devices and the change



from soft (leather) to hard (plastic) sockets may in some cases have contributed to this minority opinion.

Specific Activities Performed. Table 2 presents a tabulation of specific dressing activities in which unilateral arm amputees reported performance with their prostheses. Since this listing is based upon the responses of the subjects to open-end questions, it should be considered minimal and indicative rather than comprehensive.

Table 2

SPECIFIC DRESSING ACTIVITIES PERFORMED BY UNILATERAL ARM AMPUTEES USING A PROSTHESIS

(Times Cited)

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Grasp shoelace to tie	105	58	1
Grasp necktie for tying	88	51	5
Grasp pants to tuck in shirt	59	29	4
Grasp and pull edge of sleeve to unbutton sleeve	54	21	1
Grasp and pull up pants	33	2	0
Grasp or support pants to pull belt through loops	28	15	1
Grasp and pull up socks	13	7	0
Grasp and pull coat off hanger	6	5	2
Grasp electric razor	4	0	0
Grasp and pull off watchband	3	2	0
Grasp and pull on glove	3	2	0
Grasp washcloth	2	0	1
Grasp shirt sleeve to remove from good arm	1	1	1
Grasp nail file for filing	1	1	0
Grasp aftershave lotion and hair tonic	1	0	0
Pull on artificial leg	1	0	1
Grasp towel to dry hand	0	1	0
Grasp comb to cut own hair	0	2	1
Grasp and pull up zipper	1	3	1

The major significance of the data in Table 2 lies in their indication of the use potential in existing prostheses. Equally important, however, is the corollary question, *Why is this potential not fully utilized by amputees?* For example, 88 below-elbow, 51 above-elbow, and 5 shoulder-disarticulation amputees claimed that they held one end of a necktie with the prosthesis while they tied the knot with their "good" hand. This circumstance would suggest that the activity is perfectly feasible for all three amputee types and that it might almost be considered a "typical" or "normal" prosthetic activity. Nevertheless, the fact remains that a considerable number of amputees tie their neckties using the "good" hand alone. Presumably it is "easier" or more convenient for them to employ the one-handed method, but whether the reason is related to prosthetic difficulty, lack of motivation to use the prosthesis, or prior habit pattern is not readily apparent. More intensive study in this area might be extremely fruitful in gaining deeper insight into the problems of prosthetic utilization.

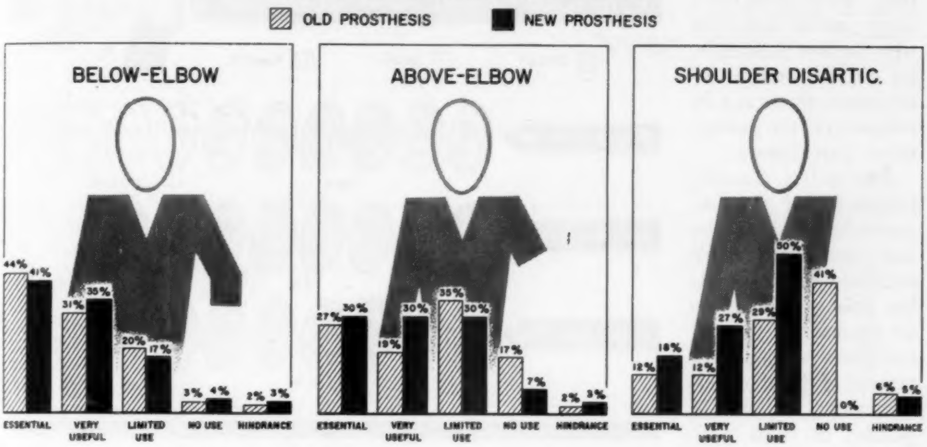
Work

Usefulness. As a result of the research program, all amputee types except the below-elbow showed an increase in positive attitude toward the usefulness of prostheses in their work. The shift in opinion was quite marked in the shoulder-disarticulation group but less apparent with the above-elbow subjects. Although the below-elbow amputees as a whole indicated little change in usefulness between the old and the new prostheses, their opinions of both prostheses were generally high.

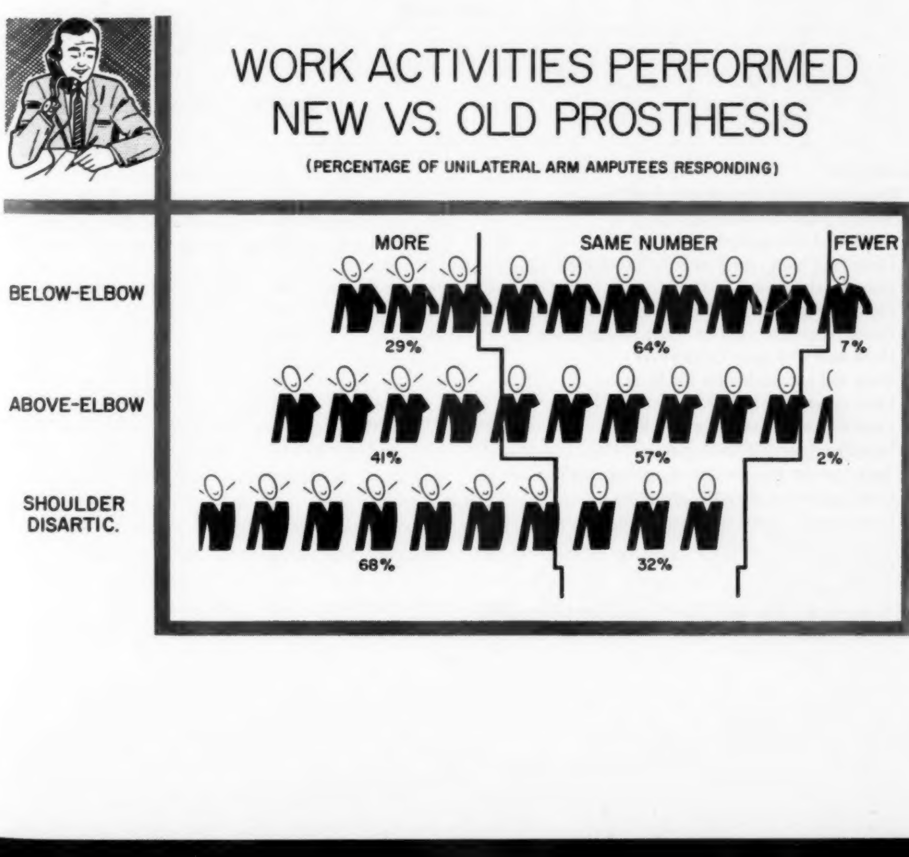
In spite of apparent improvement with the new prostheses, many of the amputees (below-elbow, 24 percent; above-elbow, 40 percent; shoulder disarticulation, 55 percent) felt that their prostheses were of little or no value to them on the job. Since, however, these percentages are much lower than the corresponding ones for the two activities previously discussed, it would appear that amputees consider

USEFULNESS OF PROSTHESIS AT WORK

(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)



their prostheses more useful for work than for either eating or dressing. The reason may be that eating and dressing involve a relatively small number of activities, many difficult to perform with a prosthesis, while vocational activities present a much broader variety of tasks of which perhaps many can be performed better with a prosthesis than without one.



Activity Level. Sixty-eight percent of the shoulder-disarticulation subjects reported that they performed more work activities with the new prosthesis. So did 41 percent of the above-elbow and 29 percent of the below-elbow participants.

Ease of Use. A major proportion of the amputees believed that the new arm made work activities easier. Holding this opinion were 63 percent of the below-elbow subjects, 75 percent of the above-elbow amputees, and 76 percent of those with shoulder disarticulations. Although this result represents a more uniform and significant "positive shift" than that found for either eating or dressing, one in eight of the below-elbow amputees felt that

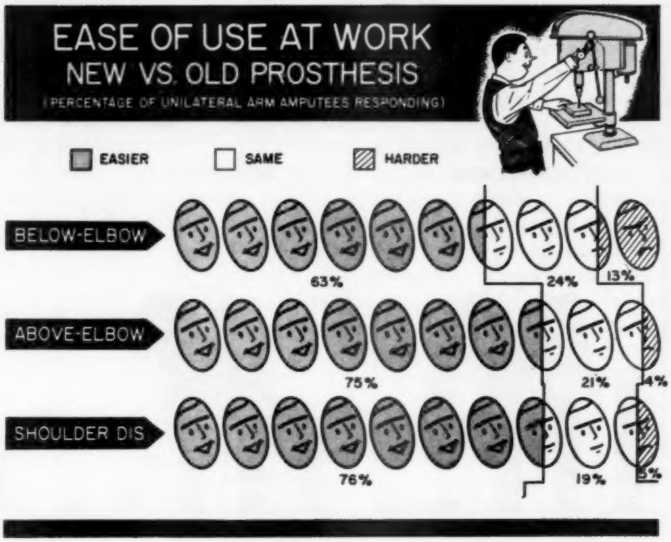


Table 3

SPECIFIC WORK ACTIVITIES PERFORMED BY UNILATERAL ARM AMPUTEES USING A PROSTHESIS
(Times Cited)

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Light Work			
Grasp and carry papers and folders	53	48	8
Weight paper for writing	41	45	13
Grasp and sharpen pencil	22	25	4
Grasp and turn crank on pencil sharpener	2	1	0
Hook briefcase and carry	16	15	3
Grasp order book or clipboard for writing	13	11	1
Grasp telephone receiver while taking notes	13	7	0
Hook and pull open file drawers	11	5	0
Push and spread folders for filing	8	11	1
Push typewriter keys	9	3	0
Push typewriter carriage	5	2	0
Weight typewriter space bar	4	2	0
Push keys or pull handle on adding machine	4	4	1
Grasp paper to place in typewriter	2	0	0
Grasp paper to put on paper clips	5	2	0
Grasp letters for sorting	5	5	0
Grasp ink bottle	3	3	2
Push lever on stapler	2	0	0
Grasp time cards and place in position for punching	0	1	0

Table 3—*Continued*

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Medium Work			
Drawing (push T-squares, triangle, rulers)[a]	8	12	0
Operate industrial machine	8	4	0
Grasp rope and tie knots	3	2	0
Hook and pull handle on drill press	2	0	0
Grasp bills to make change	2	0	0
Grasp trowel to set cement blocks[a]	2	0	0
Grasp metal while operating boring machine	1	1	0
Grasp test tubes and flasks	1	3	3
Grasp and set type	1	0	0
Grasp plates to feed printing press	1	0	0
Operate truck-weighing scale	1	0	0
Heavy Work			
Hook, lift, and carry objects up to 150 lb.[a]	33	32	5
Drive tractor, general[a]	8	9	0
Drive truck, general (shift foot gears, steer)	8	4	0
Push plow[a]	5	0	1
Hook and carry bales of hay	4	6	0
Support scoop shovel for shoveling grain	1	1	0
Grasp and swing axe or sledge hammer	1	2	0
Change tires on car	1	1	0
Push or pull hand carts	0	5	1
Grasp sacks for emptying	0	2	0
Support in lifting hospital patients	0	1	0
Miscellaneous			
Grasp and tear cloth	2	0	0
Grasp grease rag for checking oil stick	1	3	0
Push or pull and lift car hood	1	2	0
Hook and carry tires	1	1	0
Grasp syringe for drawing blood	1	1	0
Grasp fire extinguisher to recharge	1	0	0
Push and pull open elevator doors	1	0	0
Weight and push material through sewing machine	0	2	1

[a] Also performed by some amputees as a home or recreational pursuit.

work activities were harder to perform with the program prosthesis. The basis for this minority opinion was not apparent from the data.

Specific Activities Performed. The specific work activities that amputees can perform with their prostheses, and the kinds of jobs they can hold successfully, are of considerable interest from the viewpoint of vocational rehabilitation. Table 3 presents a listing of vocational activities reported by the 168 below-elbow, 158 above-elbow, and 23 shoulder-disarticulation amputees involved in the study. Activities reported by the subjects have been classified arbitrarily as light work (*i.e.*, activities typical of white-collar workers), medium work (*i.e.*, activities typical of artisans and mechanics), heavy work (*i.e.*, farming and

other heavy manual occupations), and miscellaneous. Although this listing does not reveal the full story of the employability of unilateral arm amputees, it does indicate trends. While a detailed analysis of the subject is not possible at this time, it is apparent that unilateral arm amputees are capable of a wide variety of work activities and are employable in a wide range of occupations.

An additional interesting aspect of the relationship between vocation and amputation was provided by amputee responses to two questions asked at the conclusion of the study. These questions and the answers provided by 349 subjects in the study were:

HAVE YOU CHANGED YOUR OCCUPATION SINCE YOU FIRST ENTERED THE ARM PROGRAM?

	Yes	*No*
Below-Elbow	39	129
Above-Elbow	30	128
Shoulder Disarticulation	4	19
	—	—
Totals	73	276

IF ANSWER IS "YES," HOW DID YOUR ARM INFLUENCE THIS CHANGE?

	Below-Elbow	*Above-Elbow*	*Shoulder Disarticulation*	*Total*
No influence	23	21	2	46
Provided greater efficiency or function	5	4	0	9
Provided better appearance	1	0	0	1
Miscellaneous	1	1	1	3
Reason not given	9	4	1	14
	—	—	—	—
Totals	39	30	4	73

From these data it is evident that, while one in five amputees changed jobs during the course of the study, few of the changes were attributed to the new prosthesis. Of the total number of subjects in the study, therefore, very few felt that the new prosthesis affected their employment. Consideration of the type of job change made by the amputees also fails to reveal any significant trend. None of the changes reported (student to farm hand, post-office clerk to wholesale manager, hospital attendant to repairman, unemployed to guard, janitor to stock clerk) indicated any marked shift in vocational status, either positive or negative. It must be concluded, therefore, that the prostheses provided in the study had little apparent effect on the employment status of the participants.

Recreational and Social Activities

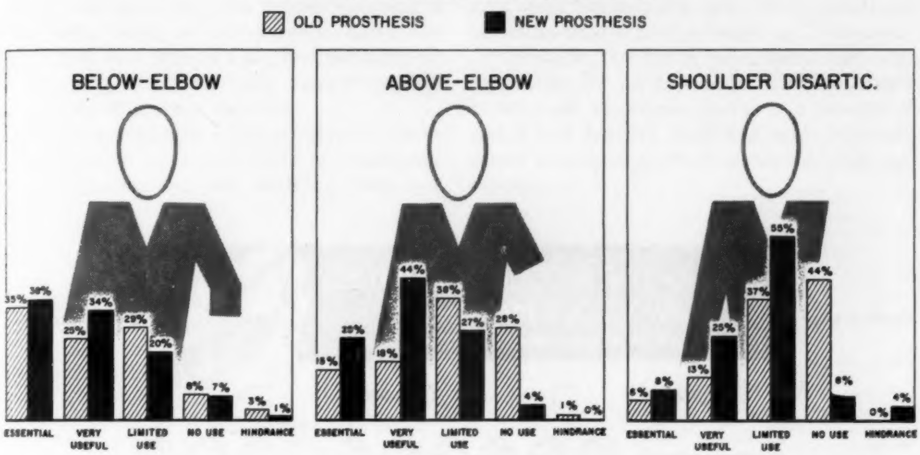
Usefulness. All amputee groups reported that in recreational and social activities the program prosthesis was an improvement over the old prosthesis. As with the activity areas previously discussed, improvement was least marked in the below-elbow subjects, but even this group showed a change for the better. For example, 72 percent of the below-elbow sample considered that their new prosthesis was either essential or very useful as against 60 percent for the old prosthesis. Shoulder-disarticulation amputees reflected a greater degree of improvement, 33 percent reporting essential or very useful for the new prosthesis as compared with 19 percent for the old. Above-elbow amputees appeared to obtain the most benefit from their new prostheses, the proportions rating their prostheses in the upper two categories of the scale being: new arm, 69 percent; old arm, 33 percent. The proportion of amputees reporting that the prosthesis was of little or no use or was a hindrance in leisure-time activities (below-elbow, 28 percent; above-elbow, 31 percent; and shoulder disarticulation, 67 percent) was greater than for vocational activities but less than for eating and dressing.

Activity Level. A significant number of amputees used their new prostheses for additional leisure-time activities. One third of the above-elbow and shoulder-disarticulation subjects and one fourth of the below-elbow subjects had found new uses. A very small proportion of above-elbow and below-elbow amputees reported decreased usefulness (3 percent and 5 percent respectively).

Ease of Use. More than 50 percent of all the amputees felt that the performance of social and recreational activities was easier with the new arm. A small number of below-elbow (7 percent) and above-elbow (3 percent) subjects felt that activities in this area were harder to do.

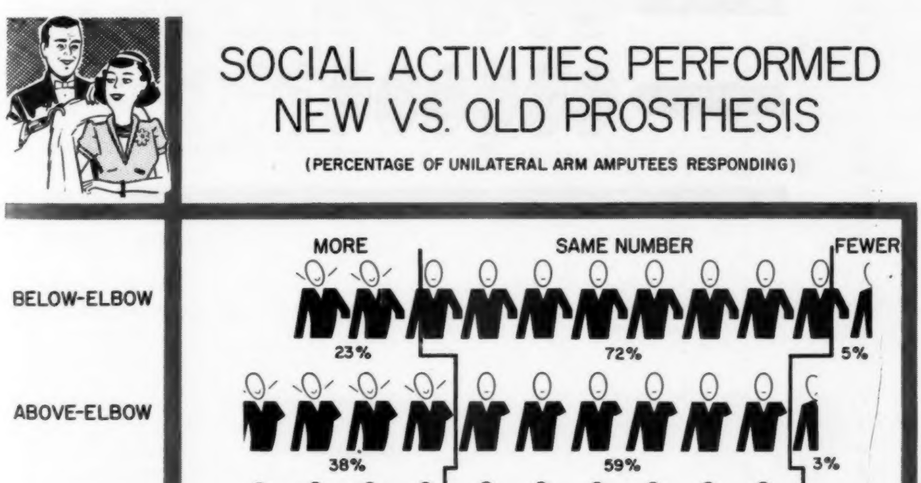
USEFULNESS OF PROSTHESIS IN SOCIAL ACTIVITIES

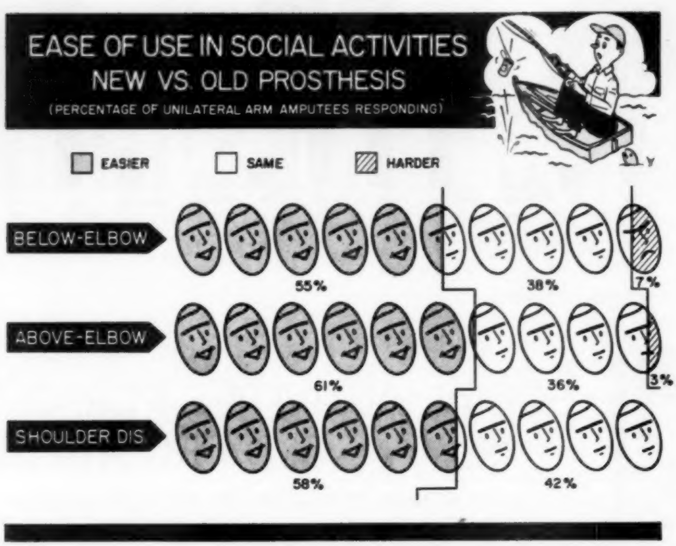
(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)



SOCIAL ACTIVITIES PERFORMED NEW VS. OLD PROSTHESIS

(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)




EASE OF USE IN SOCIAL ACTIVITIES
NEW VS. OLD PROSTHESIS
(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)
EASIER
SAME
HARDER
BELOW-ELBOW
55%
38%
7%
ABOVE-ELBOW
61%
36%
3%
SHOULDER DIS.
58%
42%

Specific Activities Performed. Table 4 presents a listing of leisure-time activities performed by unilateral arm amputees using a prosthesis. Some of the pursuits listed are performed vocationally also, but the subjects in the study mentioned them more frequently as a hobby than as a vocation.

While an amputee's social or hobby interests are perhaps not of the same level of importance as eating, dressing, and working, they are nevertheless quite significant in his total pattern of living. It is apparent that to many arm amputees a major value of the prosthesis in leisure-time activities resides in its cosmetic contribution, this factor being mentioned most frequently by all types. In addition, many found their prostheses useful in a variety of sports and hobbies, including such relatively active endeavors as hunting, fishing, golf, and baseball.

Table 4

SPECIFIC RECREATIONAL AND SOCIAL ACTIVITIES PERFORMED BY UNILATERAL ARM AMPUTEES USING A PROSTHESIS

(Times Cited)

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Sports and Recreations			
Grasp fishing rod	43	51	3
Grasp hook to bait	24	34	2
Grasp and turn fishing reel	10	6	0
Grasp hook and pull out of fish's mouth	5	7	0
Grasp fishing line	0	1	0
Grasp or support rifle to shoot or reload	40	18	3
Grasp cards to play	35	24	1
Support partner in dancing	16	24	5
Grasp golf club or baseball bat to swing	7	0	0
Grasp reins to ride horse	7	2	0
Support cue stick to shoot pool	7	7	0
Use for balance in bowling	3	3	0
Grasp canoe paddle	2	1	0
Driving			
Weight steering wheel[a]	19	7	1
Hook cross-piece of steering wheel or knob[a]	9	2	1
Grasp gear shift[a]	17	6	0
Grasp and pull throttle on plane	1	1	0
Miscellaneous			
Wear for appearance at church, social functions, etc.[a]	79	78	17
Support camera to take pictures	6	3	1
Grasp picture negative and place in developer[a]	2	1	0
Grasp newspapers or books to read	19	8	3
Grasp match box to light match	11	10	0
Grasp cigarette package	4	5	0

[a] Also performed as vocational activities.

Home Tasks

Usefulness. Use of a prosthesis at home encompasses a wide variety of tasks, from washing dishes and sweeping floors to gardening, painting, and electrical and plumbing repairs. Some of these activities are, of course, basically of a vocational nature but are performed as avocations on a part-time or intermittent basis. As for improvement in the usefulness of the prosthesis in home tasks, the shift in opinion was relatively small in below-elbow subjects but quite pronounced in above-elbow and shoulder-disarticulation amputees. In home tasks, as in other activity areas discussed previously, a high percentage of below-elbow subjects (70 percent) considered their old prostheses either essential or very useful, and this opinion was maintained for the new prosthesis (73 percent). It would appear that for this type of amputee there was less margin for improvement and hence less was achieved, or, the other way round, the old arms available for below-elbow amputees were relatively more satisfactory than were those available for other amputee types.

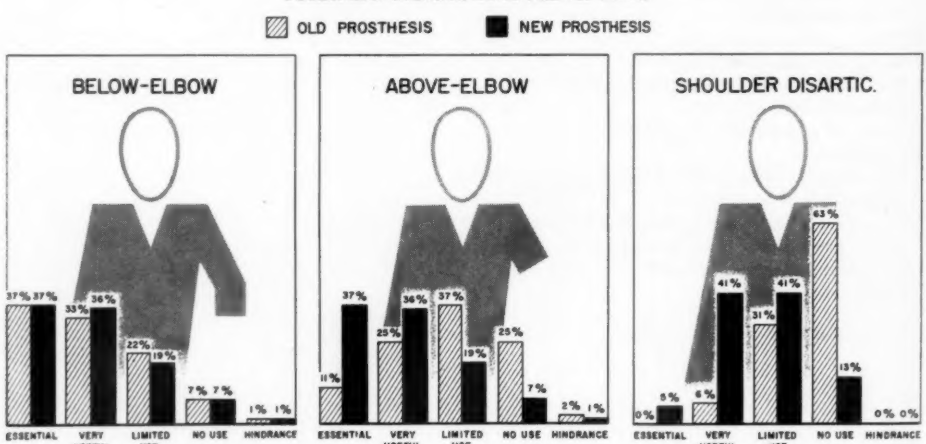
Activity Level. Nearly 45 percent of the above-elbow and shoulder-disarticulation cases and a smaller proportion of the below-elbow amputees (28 percent) found new uses in the home for their program prostheses. A small minority of the below-elbow group (6 percent) found fewer uses for their new prostheses.

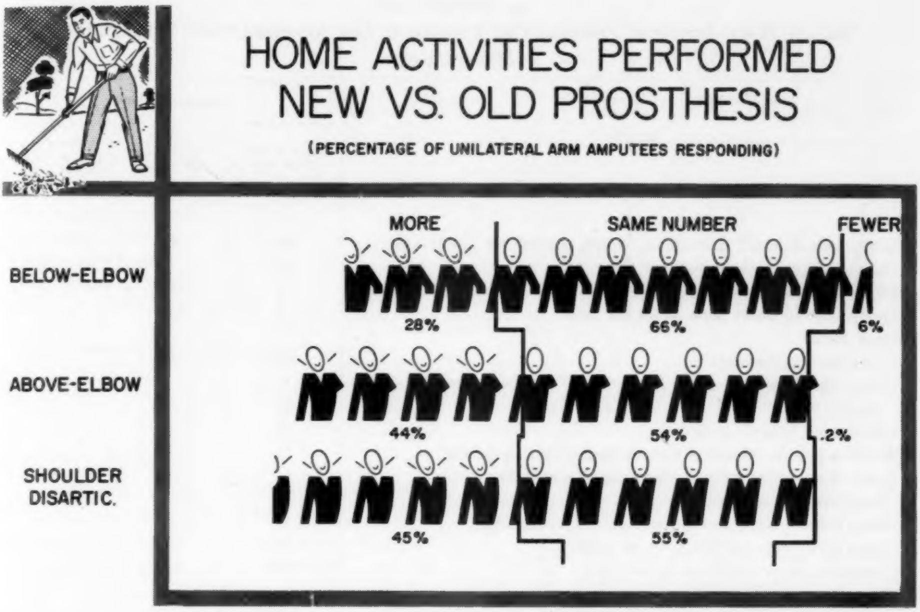
Ease of Use. The proportion of amputees reporting greater ease in performance of home tasks with the program prostheses ranged between 64 and 75 percent. Shoulder-disarticulation amputees (75 percent) were most favorably impressed, followed by above-elbow (66 percent) and below-elbow (64 percent). A few below-elbow (9 percent) and above-elbow (3 percent) subjects found home tasks more difficult than before.

Specific Activities Performed. Table 5 indicates the types of home activity for which unilateral amputees used their prostheses. From the scope of activities listed, it is apparent that unilateral amputees find a wide range of uses for their prostheses in the home. While the rate or quality of performance is not indicated by the data, several of the tasks performed imply a high degree of dexterity. For example, a number of amputees undertook automobile and electrical repairs and various types of carpentry, and they made use of a wide range of tools, including power equip-

USEFULNESS OF PROSTHESIS IN THE HOME

(PERCENTAGE OF UNILATERAL ARM AMPUTEES RESPONDING)





ment. Since, as mentioned earlier, many tasks performed in the home by choice or necessity are vocational in nature, a more intensive investigation of this performance pattern would throw further light on the employment potential of arm amputees.

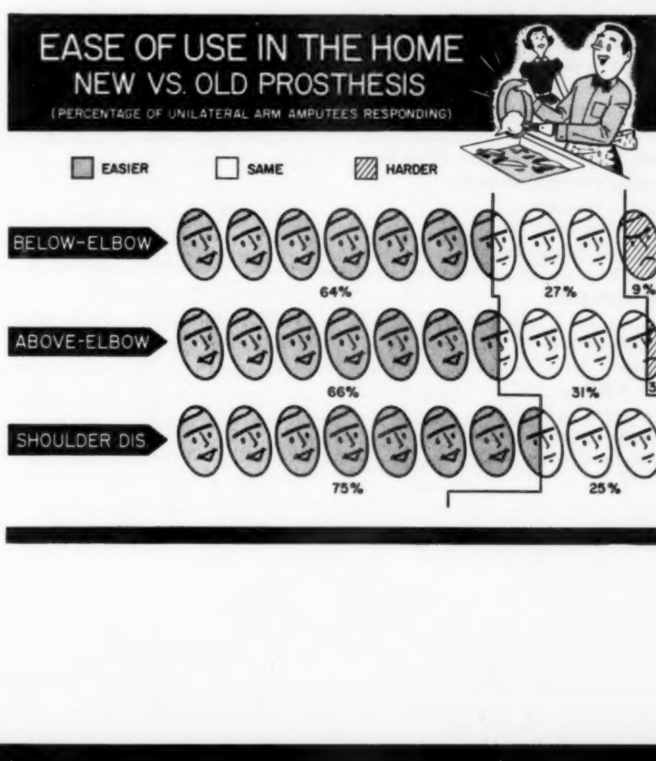


Table 5

SPECIFIC HOME ACTIVITIES PERFORMED BY UNILATERAL ARM AMPUTEES USING A PROSTHESIS

(Times Cited)

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Gardening			
Grasp long-handled tools (rake, broom, shovel, hoe, pitchfork)[a]	90	60	9
Grasp and push lawnmower	55	31	3
Grasp and push wheelbarrow	8	13	3
Grasp hose to water lawn or fill gas tank[a]	5	12	2
General Repairs			
Grasp nails to hammer[a]	66	55	9
Grasp short-handled tools (files, brace and bit, wrench, power tools)	50	36	5
Grasp paint buckets to carry	30	30	4
Perform general electrical repairs (radio, toaster, wiring)	18	15	1
Grasp small objects (light plugs, sockets, switches, etc.)	17	26	9
Grasp wood to saw or sand	13	15	3
Grasp screws, nuts, and bolts	12	15	2
Grasp spray gun, welding iron, or solder	10	11	1
Grasp and support lumber in carrying	10	3	2
Grasp rungs to climb ladder	10	1	1
Grasp chisel to hammer	8	2	0
Grasp and turn knobs on lathe[a]	5	0	0
Grasp knob to plane	3	2	0
Build fences	3	4	0
Push wood through power saw	3	2	0
Perform automobile repairs	3	2	0
Grasp nail to drive in wall	2	1	0
Grasp shovel to mix cement	1	0	0
Put up television aerial	0	4	0
Grasp barbed wire to string[a]	0	2	0
Hook to stabilize oneself on ladder	1	4	0
Grasp and pull leather to upholster chair	0	1	0
Domestic Duties			
Grasp storm sash, screens, curtain rods to put up	13	7	0
Support and carry groceries, packages[a]	12	29	7
Hook and carry garbage cans	11	4	2
Grasp dishes to wash and dry	9	6	3
Grasp, push, and pull vacuum cleaner	7	3	0
Grasp, push, or pull bed sheets and blanket to make beds	7	3	1
Grasp and carry furniture	4	9	2
Push furniture	3	3	1
Grasp dust pan to sweep up	3	2	0
Grasp and lift rugs	2	0	0
Grasp towel to dry dishes	2	0	0
Grasp knife to sharpen	2	1	1
Grasp picture frame to hang	1	0	0

Table 5—*Continued*

Activity	Amputation Level		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
Miscellaneous			
Push open and close doors	10	14	3
Support books to carry	4	5	0
Push light switch	3	3	2
Push or pull faucets	1	2	0
Push to ring doorbells	1	2	0
Grasp and pull to open doors	1	1	0

[a] Also performed by some amputees in their work.

BILATERAL SUBJECTS

In the performance of bimanual activities by unilateral arm amputees, the prosthesis serves primarily, as has been seen, to assist the remaining good hand. Similarly, and for various reasons, unilateral arm amputees not infrequently perform with the one remaining hand activities ordinarily bimanual. Bilateral arm amputees quite obviously are faced with an entirely different situation. Since more or less of both upper extremities is lacking, at least one prosthesis must assume more than an assistive role, and one-handed performance of tasks normally two-handed cannot be substituted for use of a prosthesis. Manual activities required of bilateral arm amputees must therefore be done prosthetically if done at all. In a very real sense, then, the performance problems and the adaptations of bilateral arm amputees are quite unlike those of any type of unilateral amputee, and they therefore warrant separate discussion.

In the Upper-Extremity Field Studies, data were collected on 10 bilateral arm amputees (7 bilateral below-elbow, 3 bilateral above-elbow/below-elbow). Five of these subjects (4 bilateral below-elbow, 1 bilateral above-elbow/below-elbow) were wearing prostheses bilaterally when admitted. The other five had either one prosthesis only or none at all. Thus, although information as regards program prostheses was obtained on all 10 subjects, comparative data on new *vs.* old arms are available on only five subjects.

Experienced Wearers

Although the five amputees who had worn prostheses bilaterally prior to the NYU Field Studies rated their old arms quite useful in all five of the activity areas, they considered the new prostheses equally useful or slightly better than the old ones (Table 6).

As shown in Table 7, four of the five experienced wearers of bilateral prostheses indicated equivalent or increased use of their new prostheses as compared to the old, while one reported decreased use.

Table 6
USEFULNESS OF ARM PROSTHESES TO BILATERAL WEARERS
NUMBER OF SUBJECTS RESPONDING
(N = 5)

Activity Area	Rating					
	Essential		Very Useful		Limited Use	
	Old	New	Old	New	Old	New
Eating	5	5	0	0	0	0
Dressing	3	5	1	0	1	0
Work	5	5	0	0	0	0
Recreation	4	4	1	1	0	0
Home	5	5	0	0	0	0

Table 7
ACTIVITIES PERFORMED BY BILATERAL ARM WEARERS
NEW *vs.* OLD PROSTHESES
NUMBER OF SUBJECTS RESPONDING
(N = 5)

Activity Area	More	Same No.	Fewer
Eating	2	2	1[a]
Dressing	2	2	1[a]
Work	2	2	1[a]
Recreation	1	3	1[a]
Home	2	2	1[a]

[a] At Evaluation II this subject complained of the poor fit and operation of the left prosthesis provided him in the Field Studies. The deficiencies of this prosthesis are reflected in his opinions concerning extent of use and ease of operation in all activity areas. See Table 8.

As might have been anticipated, the pattern of amputee responses concerning ease of use (Table 8) of the new prostheses as compared with the old was quite similar to that concerning extent of use (Table 7). In general, the evidence indicated somewhat easier operation of the program prostheses, although the improvement was by no means universal.

Those bilateral arm amputees who reported easier operation and more extensive use of their new prostheses attributed the improvements primarily to the more secure grasp permitted by the terminal devices prescribed in the Field Studies. Neoprene-lined hook fingers and the heavy-load feature of the Northrop-Sierra two-load hook contributed greatly to this improved grasp security. Other favorable aspects of the new arms, mentioned by different subjects, were lighter weight and better control (faster operation and lower force requirement). The one subject fitted with an above-elbow arm indicated that operation of his new elbow lock was simpler and more efficient.

Table 8
EASE OF USE FOR BILATERAL ARM AMPUTEES
NEW *vs.* OLD PROSTHESES
NUMBER OF SUBJECTS RESPONDING
(N = 5)

Activity Area	Easier	Same	Harder
Eating	3	1	1[a]
Dressing	3	1	1[a]
Work	2	2	1[a]
Recreation	1	3	1[a]
Home	2	2	1[a]

[a] At Evaluation II this subject complained of the poor fit and operation of the left prosthesis provided him in the Field Studies. The deficiencies of this prosthesis are reflected in his opinions concerning extent of use and ease of operation in all activity areas. See Table 7.

New Wearers

The five amputees who had not worn prostheses bilaterally prior to the Field Studies rated their program prostheses quite useful (Table 9). For some reason, however, their ratings showed less enthusiasm than did those of the patients who had previously worn prostheses.

Table 9
USEFULNESS OF THE PROSTHESES TO NEW BILATERAL WEARERS
NUMBER OF SUBJECTS RESPONDING
(N = 5)

Activity Area	Essential	Very Useful	Limited Use
Eating	3	2	
Dressing	2	2	1
Work[a]	3	1	
Recreation	2	3	
Home	2	2	1

[a] One subject was unemployed.

Specific Activities Performed

At Evaluation II (new prostheses), information on the specific uses to which bilateral arm amputees put their prostheses was obtained from all 10 subjects for each of the activity areas under study. The activities reported by the individual amputees were given as "free responses" (*i.e.*, unprompted

and unstructured), and hence the listings may be considered more representative than complete.

The available data on the 10 bilateral subjects indicate that they used their prostheses extensively in eating and attained a relatively high level of independence. Two mentioned specifically that they performed all eating activities with their new prostheses (*i.e.*, were completely independent). Table 10 presents specific eating activities reported to be performed by the bilateral subjects.

Table 10

SPECIFIC EATING ACTIVITIES PERFORMED BY BILATERAL ARM AMPUTEES USING PROSTHESES (N = 10)

Activity	Times Cited
Use fork to bring to mouth	9
Use knife and fork to cut food	7
Pick up glass or cup to drink	7
Grasp spoon to stir coffee or for eating	5
Butter bread	3
Open bottles and drink from them	2
Grasp plates	2
Grasp and carry a tray	1
Grasp and eat an ear of corn	1

Only one of the 10 bilateral amputees claimed complete independence in dressing, although two other subjects reported the performance of all dressing activities except buttoning shirt sleeves. Two more persons performed all activities except fastening buttons, lacing shoes, and tying neckties. Table 11 lists specific dressing activities reported as performed by the bilateral subjects.

The employability or vocational-placement possibilities of bilateral arm amputees always hold considerable interest. Although the sample was in this instance exceedingly small, it may be worth noting that five of the 10 bilateral amputees were self-employed, that four worked for others, and that only one was unemployed. Of the nine employed subjects, one was a lawyer, one an engineer, one a forester, and one a quality-control inspector. Two were filling-station attendants, and three were farmers. The quality-control inspector, unemployed at the beginning of the program, obtained his position after receiving his new prostheses, and he credited the functional qualities of the limbs for his new employment.

Table 11

SPECIFIC DRESSING ACTIVITIES PERFORMED BY BILATERAL ARM AMPUTEES USING PROSTHESES (N = 10)

Activity	Times Cited
Pull on trousers, shirt, and socks	7
Pull off shirt	7
Tie shoelaces	3
Button and unbutton shirts	3
Grasp and pull zipper	2
Shave	2
Tie necktie	1
Fasten belt	1
Fasten snaps on shoes	1
Brush teeth	1
Wash and dry face	1

Table 12 lists specific activities reported by the nine employed subjects as being performed with their program prostheses at work.

A listing of recreational activities performed by the bilateral amputees revealed that with their new arms most were able to drive a car independently and that most engaged in some form of active or passive recreational endeavor. Table 13 lists specific activities mentioned by the subjects as being performed with their prostheses.

The pattern of home activities performed by bilateral amputees (Table 14) does not differ greatly from that of unilaterals except that among bilaterals there is a lesser tendency to undertake tasks requiring fine manipulation. Even allowing for the smaller number of subjects involved, it is apparent that the home activities of bilaterals run more to gross tasks, such as pushing a lawnmower or handling a broom, than to precision activities, such as electrical or radio repairing. Since the absence of "at least one good hand" would be a major handicap in work requiring manipulation of small parts, such a situation is quite understandable.

Table 12

SPECIFIC WORK ACTIVITIES PERFORMED BY BILATERAL ARM AMPUTEES USING PROSTHESES
(N = 9)

Activity	Times Cited
General Office Duties	
Grasp pencil and write	4
Grasp telephone	2
Push cash-register keys	2
Push keys to type	2
Pull lever on adding machine	1
Hook briefcase	1
Push down on stapler	1
Grasp and carry magazines, books, paper, chair	1
Grasp and sharpen pencil	1
Farming and Forestry	
Grasp hammer and drive nails	4
Grasp small tools (spade, saw)	3
Plow	2
Weed	2
Grasp hoe, dig potatoes	2
Hook and carry buckets	1
Trim trees, use hand saw	1
Grasp animals	1
Set animal traps	1
Grasp surveyor's rod	1
Grasp measuring tape	1
Plant, general	1
Garden, general	1
Bale hay	1
Gas-Station Operation	
Grasp and take off gas-tank cap	2
Operate gas pump	2
Put water in radiator	2
Check oil	2
Grasp and handle money	2
Grasp rag to wipe windshield	1
Grasp broom to sweep	1
Clean tables	1
Carry soda cases	1
Open beer bottles	1
Grasp sponge to wipe dishes	1

In summary, the comparative data on five bilateral arm amputees whose preprogram prostheses were replaced by program arms appeared to indicate that:

1. The five subjects thought well of their old prostheses and used them extensively.

Table 13

SPECIFIC RECREATIONAL ACTIVITIES PERFORMED BY BILATERAL ARM AMPUTEES USING PROSTHESES
(N = 10)

Activity	Times Cited
Grasp steering wheel to drive	6
Grasp, push, and pull gear shift	6
Grasp and pull switch for headlights	6
Grasp and pull playing cards	3
Grasp fishing pole	2
Grasp cigarettes to take out of pack	2
Grasp and turn fishing reel	1
Grasp hook to bait	1
Grasp or support rifle to shoot or reload	1
Grasp camera, trip shutter, wind film	1
Grasp and pitch horseshoes	1
Grasp, pull starter, and steer motorboat	1
Grasp and throw softball	1
Push checkers to play	1
Grasp newspaper to read	1

2. In four of the five cases there was slight but definite evidence of functional improvement over that provided by the old prostheses. Contributing largely to this improvement appeared to be the better grasp furnished by the Dorrance 5X and Northrop-Sierra two-load hooks, partly because of the neoprene-lined hook fingers and partly because of the heavy-load feature of the Northrop-Sierra device. Other favorable features mentioned by some of the subjects were lightness and ease of operation. The one amputee fitted with an above-elbow prosthesis felt that his new elbow was much more dependable and much easier to operate than the one previously worn. One subject in the group apparently had a left prosthesis very poorly fitted and functionally inadequate, a deficiency which, in view of the rigorous checkout procedures and the close control of fittings by the clinic teams, is hard to explain. Nevertheless, that particular patient was obviously fitted unsatisfactorily, and this circumstance affected his whole reaction to the prostheses provided.

DISCUSSION

An outstanding characteristic of the data thus far presented is general consistency. For all categories of daily-living activities considered (eating, dressing, work, recreational and social life, and home tasks), and for all criteria applied (general usefulness, level of usage, and ease of use), the evidence strongly indicates that the prostheses provided in the program were more useful than those previ-

Table 14

SPECIFIC HOME ACTIVITIES PERFORMED BY BILATERAL ARM AMPUTEES USING PROSTHESES (N = 10)

Activity	Times Cited
Gardening	
Grasp and push lawnmower	7
Grasp rake, hoe, and broom	2
Grasp hose to water lawn or garden	2
Grasp shears and trim hedges	1
General Repairs	
Hook paint bucket and grasp brush to paint	3
Grasp hammer and nails	2
General repairs	1
Rewire electrical equipment	1
Grasp saw to cut wood	1
Domestic Duties	
Grasp broom, brush, and dustpan	5
Grasp and carry groceries	2
Wash dishes	2
Make beds	2
Move furniture	2
Push vacuum cleaner	1
Grasp rug to dust	1
Hook and carry garbage cans	1
Miscellaneous	
Open doors	4
Push light switch	3
Grasp and turn faucet	1
Grasp padlock and unlock	1
Grasp brush to wash car	1

ously worn. But the material also raises a number of interesting questions of which only some can be answered satisfactorily by the available data. For example, the extent of improvement provided by the new prostheses varied considerably from amputee type to amputee type. It was least for the below-elbow subjects, and some few members of this group even expressed a preference for the old prosthesis. For the unilateral above-elbow and shoulder-disarticulation subjects, the increased usefulness of the new prosthesis was considerably more marked and dramatic.

When one speculates on the reasons for these differences, it must be borne in mind that the so-called "old" prostheses exhibited a wide range of quality from very poor to excellent. A number of the preprogram arms, particularly those for below-elbow amputees, were probably as good as, in some few cases even better than, those provided in the study. Moreover, some of the below-elbow subjects whose old leather-socket arms had some of the comfort qualities of old shoes or slippers reacted unfavorably to the new plastic sockets. Whatever the reasons, it was evident that some of the old arms provided below-elbow amputees with a relatively high degree of usefulness and that the impact of the research program on these subjects was relatively small. The reverse appears to have been true of above-elbow and shoulder-disarticulation prostheses. Taken as a whole, the old arms for these cases were of comparatively limited usefulness, and hence considerable improvement was effected by the new prostheses. Thus it may be said that the prostheses provided in the field program made the greatest contribution where improvement was most needed.

Another thought-provoking finding of the study was that the usefulness of the prostheses obviously varied from one activity area to another, sometimes quite significantly. All three unilateral groups rated their prostheses as being about equally useful in home, work, and social activities but considerably less useful in dressing and of least use in eating. An explanation of these differences may lie in the fact that eating and dressing involve a limited number of specific activities, particularly those which require bimanual effort, and that the majority of these are quite difficult to perform with an arm prosthesis. It may also be conjectured that, in the sometimes quite lengthy time lapse between amputation and receipt of an arm prosthesis, patients build strong habit patterns of one-handed eating and dressing and that these habits carry over after the prosthesis has been supplied. Work, leisure, and home tasks present a much wider and more varied range of activities. Presumably more of these require bimanual performance in which the prosthesis is of definite assistance. Bilateral arm amputees gave uniformly high ratings to their prostheses in all activity groups, but *their* performance

problems are quite different from those of unilateral arm amputees.

A third area of interest involves the matter of basic reasons for use or nonuse of the prosthesis. In numerous instances, a particular activity was performed with the prosthesis by a considerable number of amputees of a given type. Why, then, do not *all* amputees of that type perform that activity with the prosthesis? Here is a question with many implications. It has been suggested that of the factors determining prosthetic usage—such as ease and convenience of performance, motivation, habit patterns—the first named is of basic importance. If, for example, we consider some specific activity such as tying shoelaces, which with prosthetic help apparently can be performed by *some* amputees of all types, even including a few with shoulder disarticulations, we may assume that this activity presents a certain level of difficulty and inconvenience. For below-elbow subjects the level may be low enough not to discourage more than a few from performing the task with their prostheses. But it must also be high enough so that others, by reason of habit or lack of motivation or some other influence, will tie the laces one-handed, wear loafers or buckle shoes, or in some other fashion avoid use of the prosthesis. For above-elbow and shoulder-disarticulation amputees, of course, the difficulty in performing the activity rises progressively and markedly, so that even though the performance potential be available with the prosthesis fewer amputees would be inclined to avail themselves of it. Obviously, then, further study of the factors affecting prosthetic utilization is highly desirable.

A fourth area of interest has to do with the vocational potential of arm amputees. The number and variety of tasks that amputees can perform with the aid of an artificial arm is quite surprising. Extensive use of the prosthesis on the job, in activities around the house, and in hobbies suggests for arm amputees a much wider employment potential than is generally recognized. This subject too is worthy of further investigation on a more intensive basis than was possible in the NYU Field Studies.

In general, the relation between the pretreatment (Evaluation I) and post-treatment (Evaluation II) conditions of the five bilateral amputees was quite similar to the corresponding relation for the unilateral below-elbow amputees discussed previously. Since the bilateral sample included predominantly below-elbow fittings (4 bilateral below-elbow, 1 bilateral below-elbow/above-elbow), the similarity is not surprising. The over-all performance patterns of the 10 bilateral subjects would indicate that as a whole these patients achieved a high level of performance in a wide range of tasks. To a very considerable degree they appeared able to operate their prostheses effectively and to meet independently a substantial number of the requirements of daily living.

Extent of Use of Arm Prostheses in Twenty Selected Bimanual Activities

In the preceding section, the evaluation of the utility of prostheses provided arm amputees was based upon an analysis of their usefulness in five key activity areas, changes in activity level, and ease of use. To gain further insight in this matter, additional study was made of how amputees use their prostheses in 20 selected activities which were considered significant on the basis of four criteria:

1. The activities should be important ones drawn from all five of the areas of daily living previously discussed (*i.e.*, eating, dressing, work, social life and recreation, and home tasks).
2. The activities should call for a range of work levels from floor to head.
3. The normal performance of the activities should be bimanual.
4. Prosthetic performance of the activities should be possible for all unilateral amputee types.

The tasks selected were:

1. Cut food with knife and fork
2. Sharpen pencil
3. Sweep up dirt with brush and dustpan
4. File and clean fingernails
5. Tie necktie
6. Use telephone (particularly when taking notes)
7. Assist someone with coat
8. Take bills out of wallet
9. Unbutton shirt sleeve

10. Carry several packages
11. Use "Flit" gun
12. Open bottles, jars, and tubes
13. Put on glove
14. Use paper clip
15. Carry cafeteria tray
16. Use can or bottle opener
17. Tie shoelaces
18. Play cards
19. Rewire electric plug
20. Use hammer and nails

With regard both to preprogram and to program prostheses, the subjects were asked concerning each of the selected activities five questions:

1. How often in your routine of living does the occasion arise for you to perform the activity? (Daily, weekly, monthly, other)
2. How important is the activity in your particular pattern of living? (Very important, important, of little or no importance)
3. How often do you perform the activity with your prosthesis? (Daily, weekly, monthly, other)
4. If you do not perform the activity with your prosthesis every time the occasion arises, why not? (Write-in)
5. If you never use the prosthesis to perform the activity, how do you perform it? (Write-in)

The material that follows presents amputee responses to these questions and from these responses seeks to determine the extent to which prostheses were meeting amputee needs. In the main, attention is directed toward the new prostheses provided in the study, that particular data being considered as indicative of present status and hence more meaningful. Only in regard to Question 3, and then with respect to unilateral cases only, is a comparison made between old and new prostheses.

The subjects in this study were the same as those making up the sample for the previous series of questions. Again, the data on the three unilateral amputee groups are presented first, with those for the bilateral subjects in a separate section following.

UNILATERAL SUBJECTS

As we have seen, the problem of restoring function to unilateral arm amputees varies from amputee type to amputee type, the extent of restoration generally being related inversely to the degree of anatomical loss. But all three types of unilateral arm amputees usually have left one normal arm and hand, and accordingly the prosthesis needs for the most part only to assist the remaining natural member.

Frequency of Occasion to Perform Activities

The purpose of the question "How frequently does the occasion arise to perform the activity?" was to ascertain how often amputees were called upon, or had the opportunity, to perform each of the 20 selected activities, regardless of whether they used the prosthesis in the performance of the activity or whether they even performed it at all. For instance, the question "How often do you have occasion to cut food with a knife and fork?" was interpreted as "How often do you have food which requires cutting with a knife?" Responses relative to each of the 20 activities were tabulated in four categories—at least once daily; at least once weekly; at least once monthly; and less than once monthly, or never. Separate tabulations were prepared for below-elbow, above-elbow, and shoulder-disarticulation amputees. On the basis of these tabulations, there was calculated the percentage of amputees (of each type) who reported once daily or oftener as the frequency of occurrence of a particular activity. The percentage figures were then used to arrange the 20 activities in order from those occurring most frequently to those occurring least frequently. It should be emphasized that "most frequently," as used here, means occurring on a daily basis to the largest proportion of amputees.

Table 15 presents the results for the three groups of unilateral amputees. Since these data are based on unverifiable amputee statements concerning their activities, the information in Table 15 cannot be considered as presenting any absolute answer. Nevertheless, the data are quite consistent. Percentages for the first nine activities are of the same order for all groups, and that for the tenth shows a slight variation for the shoulder-disarticulation subjects only. The 10 tasks on the lower end of the table were performed daily by the least number of amputees. These data showed

Table 15

Percentage of Unilateral Arm Amputees Reporting Occasion for Selected Activities "at Least Once Daily"

Activity	Amputee Type		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
1. Unbutton shirt sleeve	93	87	87
2. Tie shoelaces	84	83	78
3. Cut food with knife and fork	77	87	74
4. Take bills out of wallet	80	73	78
5. Open bottles, jars, and tubes	72	70	70
6. Use telephone (particularly when taking notes)	60	75	61
7. Use paper clip	53	55	65
8. File and clean fingernails	51	48	65
9. Sharpen pencil	51	49	48
10. Use can or bottle opener	44	46	35
11. Put on glove	36	40	39
12. Tie necktie	37	35	35
13. Carry several packages	39	37	13
14. Sweep up dirt with brush and dustpan	29	28	22
15. Carry cafeteria tray	16	20	26
16. Use hammer and nails	19	19	9
17. Assist someone with coat	12	10	9
18. Use "Flit" gun	5	4	4
19. Play cards	1	6	0
20. Rewire electric plug	1	2	0

similar patterns of occurrence for each of the three types of amputees. Thus it would appear that some of the activities on the "selected" list confront a large proportion of all types of amputees on a daily basis. Other activities affect relatively few amputees as often as this.

How often an activity should occur, or how many people it should affect to be considered "significant" in the lives of amputees, is a philosophical question. On an arbitrary basis we might say that the first nine activities in Table 15, which occur daily in the lives of more than about half of the amputee population, are "significant" activities. Yet who can say that tying a necktie (occurring to one third of the group daily) or even using a hammer and nails (less than one fifth of the population affected daily) are "insignificant" activities? Obviously such tasks could be highly significant to the particular amputees involved.

Relative Importance of the Activities

In addition to the frequency of occurrence, the degree of importance subjectively attached to being able to perform a specific activity is a second significant factor in determining the usefulness of a prosthesis to its wearer. Accordingly, the ten subjects were also asked to rate each of the 20 selected activities as "very important," "important," or "of little or no importance" to them in their regular activity pattern.

Table 16 presents the percentages of amputees rating the respective activities as either "very important" or "important," the activities being arranged in the approximate order of importance on the basis of these percentages. For example, "cut food with knife and fork" was rated "very important" or "important" by more amputees within each of the three unilateral amputee groups than was any other of the 20 selected activities. Tying a necktie was second in importance to above-elbow and shoulder-disarticulation amputees but fifth in importance to the below-elbow subjects. Thus the ranking of activities in Table 16 may be thought of as indicating the general level of importance attached to the activities by the unilateral amputee population as a whole.

In these terms the 20 activities fall rather obviously into three levels of significance. The first 10 tasks are rated as important by two thirds or more of the sample, cutting food being by far the most significant activity (about 9 out of 10 subjects). The next three activities may also be considered quite significant, almost one in two amputees designating them as important. The final seven tasks may be regarded as having lower general significance, no more than one in three amputees rating them as important. With the possible exception of using a "Flit" gun, however, even these low-ranking activities cannot be considered as completely insignificant. For example, rewiring an electric

Table 16

RELATIVE SIGNIFICANCE OF ACTIVITIES TO UNILATERAL ARM AMPUTEES

(Based on Percentage of Amputees Rating an Activity Important or Very Important)

Activity	Amputee Type		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
1. Cut food with knife and fork	86	88	96
2. Tie necktie	63	79	87
3. Unbutton shirt sleeve	75	67	74
4. Use hammer and nails	67	62	83
5. Open bottles, jars, and tubes	64	64	83
6. Use telephone (particularly when taking notes)	58	72	83
7. Tie shoelaces	75	61	70
8. Take bills out of wallet	71	65	65
9. File and clean fingernails	67	73	61
10. Carry several packages	56	67	70
11. Sharpen pencil	57	50	52
12. Use can or bottle opener	57	47	39
13. Use paper clips	43	44	35
14. Assist someone with coat	40	27	26
15. Sweep up dirt with brush and dustpan	32	35	17
16. Play cards	35	20	39
17. Carry cafeteria tray	25	21	35
18. Put on glove	26	33	13
19. Rewire electric plug	20	23	22
20. Use "Flit" gun	13	10	9

plug, nineteenth in order on the list, is rated as an important activity by one in five unilateral amputees of all types, a fairly substantial number of people. We may conclude therefore that, while according to the criteria used in this study the 20 selected activities vary widely in importance, all, or almost all, have value to some significant proportion of unilateral arm amputees.

It is of interest to compare the data on the importance of activities with those on the frequency of occurrence discussed earlier. Table 17 presents the 20 activities in approximate order of frequency of occurrence (from Table 15) and also lists the approximate order of importance for the 20 tasks (from Table 16). A fairly consistent relationship between frequency and importance is apparent at once. Seven of the nine most important activities occur very frequently.

It can be inferred therefore that, in general, activities which occur most frequently are likely to be regarded as being the most important, but the instances where this principle does not hold are also of interest. Two out of three shoulder-disarticulation amputees said they had occasion to use a paper clip daily, but only one out of three considered the activity important. Less than one in six below-elbow amputees reported that they had occasion to use a hammer and nails on a daily basis, yet two out of three considered the

Table 17

RELATIVE INCIDENCE AND RELATIVE IMPORTANCE OF TWENTY BIMANUAL ACTIVITIES AMONG UNILATERAL ARM AMPUTEES

Incidence	Activity	Importance
1	Unbutton shirt sleeve	3
2	Tie shoelaces	7
3	Cut food with knife and fork	1
4	Take bills out of wallet	8
5	Open bottles, jars, and tubes	5
6	Use telephone (particularly when taking notes)	6
7	Use paper clip	13
8	File and clean fingernails	9
9	Sharpen pencil	11
10	Use can or bottle opener	12
11	Put on glove	18
12	Tie necktie	2
13	Carry several packages	10
14	Sweep up dirt with brush and dustpan	15
15	Carry cafeteria tray	17
16	Use hammer and nails	4
17	Assist someone with coat	14
18	Use "Flit" gun	20
19	Play cards	16
20	Rewire electric plug	19

activity important. While only one in three of the below-elbow subjects reported tying a necktie daily, about three in four considered it important to be able to do so. Thus, some activities that occur frequently may be relatively unimportant; others may occur only infrequently but still have great personal significance.

Performance of Activities with the Prosthesis

Having considered the frequency of occurrence of the 20 selected activities and the relative importance of these activities in the lives of amputees, we come now to the frequency of use of the prosthesis in the performance of the tasks, the point being to evaluate both the extent of prosthetic use and the relationship between this utilization and the two factors previously presented (*i.e.*, frequency of occurrence and importance).

Data on use of the prosthesis in the 20 selected activities, obtained from all amputees in the study, were organized to show the percentage of amputees who always, regardless of frequency, used the prosthesis in the performance of a particular activity, the percentage who sometimes used the prosthesis, and the percentage who never used it, a small number of amputees who claimed that they never had occasion to perform a particular activity being excluded. Table 18 presents the incidence of use of the program prostheses as reported by the unilateral subjects.

Analysis of Table 18 shows that the prosthesis is used extensively by below-elbow sub-

Table 18

PERFORMANCE OF SELECTED ACTIVITIES BY UNILATERAL ARM AMPUTEES USING PROSTHESES

(Percentage of Amputees Responding)

Activity	Amputee Type								
	Below-Elbow (N = 168)			Above-Elbow (N = 158)			Shoulder Disarticulation (N = 23)		
	Always	Sometimes	Never	Always	Sometimes	Never	Always	Sometimes	Never
1. Cut food with knife and fork	52	18	30	20	13	67	9	4	87
2. Sharpen pencil	90	1	9	76	1	23	61	9	30
3. Sweep up dirt with brush and dustpan	79	0	21	54	7	39	61	17	22
4. File and clean fingernails	74	6	20	61	8	31	53	4	43
5. Tie necktie	67	2	31	47	1	52	17	4	79
6. Use telephone (particularly when taking notes)	40	9	51	27	10	63	26	9	65
7. Assist someone with coat	75	4	21	28	5	67	0	4	96
8. Take bills out of wallet	76	6	18	53	6	41	44	4	52
9. Unbutton shirt sleeve	61	3	36	25	7	68	4	4	92
10. Carry several packages	89	3	8	85	3	12	87	0	13
11. Use "Flit" gun	85	0	15	73	3	24	22	0	78
12. Open bottles, jars, and tubes	72	9	19	50	16	34	48	4	48
13. Put on glove	82	1	17	60	8	32	41	0	59
14. Use paper clip	83	2	15	67	6	27	70	4	26
15. Carry cafeteria tray	85	0	15	55	3	42	52	0	48
16. Use can or bottle opener	76	5	19	49	7	44	39	9	52
17. Tie shoelaces	73	5	22	38	4	58	9	9	82
18. Play cards	59	11	30	41	4	55	18	30	52
19. Rewire electric plug	83	2	15	73	0	27	52	0	48
20. Use hammer and nails	83	4	13	65	2	33	65	5	30

jects in performing the 20 selected activities, all tasks save one being performed by more than 50 percent of the group every time the opportunity arose. With rare exceptions (*e.g.*, carrying packages), the utilization of the prosthesis in performing activities dropped off sharply and progressively from the below-elbow to the above-elbow to the shoulder-disarticulation groups. An intriguing and somewhat unexpected finding is the relatively small percentage of amputees reporting occasional use of the prosthesis. It would appear that amputee use of the prosthesis tends to be on an all-or-none basis. If an amputee uses his prosthesis to perform an activity at all, he tends always to use it for that activity. Even when this general tendency is violated, there are interesting areas for speculation. For example, cutting food with knife and fork has a relatively high incidence of "sometimes" responses. Since we know that cutting food is relatively difficult at all amputation levels, it seems probable that some amputees ignore the prosthesis under some circumstances (*e.g.*, eating at home) but use it on other occasions (*e.g.*, eating out or when they have company) in spite of the difficulty. The fairly general always-or-never use of the prosthesis in the performance of specific activities reinforces a conclusion presented earlier—that there is for each activity a certain threshold, or tolerance, level of difficulty associated with prosthetic performance, that this threshold varies from amputee to amputee and from activity to activity, that if the performance difficulty is within the individual's tolerance limits he will tend to use the prosthesis consistently, and that if the level of difficulty is above his limit he will tend not to use the prosthesis at all.

The data in Tables 15 through 18 may also be viewed as an index of the relative usefulness of the prosthesis in the performance of the 20 selected tasks and, conversely, as a measure of the relative difficulty of the several activities from the standpoint of accomplishment by means of a prosthesis. For instance, the activity "sharpen pencil" appears to be performed (with help from the prosthesis) by 90 percent of below-elbow, 76 percent of above-elbow, and 62 percent of shoulder-disarticulation amputees every time the occasion arises. It would appear, therefore, that sharpening a pencil is not too difficult an operation for any type of unilateral arm amputee. The corollary conclusion is that, in pencil-sharpening, the prosthesis is a highly useful assistive device. On the contrary, activities such as cutting food or holding a telephone with the prosthesis appear to be quite difficult for arm amputees at all levels, and the prosthesis is then obviously of less value.

If we extend this index-of-usefulness concept to the entire list of 20 activities, we obtain the results shown in Table 19, which presents the percentage of amputees reporting use of the prosthesis every time the occasion arose for performing the activities. If, further, it is assumed that those activities in which there is the highest degree of prosthetic utilization are activities for which prostheses are most useful (or, more simply stated, easiest to perform with a prosthesis), then Table 19 indicates that the below-elbow prosthesis is highly useful or well adapted to performance in most of the 20 activities. For above-elbow and shoulder-disarticulation subjects, the usefulness or adaptability of the prosthesis drops off sharply (*i.e.*, the prosthesis has a high level of usefulness for considerably fewer activities). Nevertheless, some consistency in pattern is evident for the three unilateral amputee types in that activities for which the prosthesis is most useful for the below-elbow group tend also to be easiest for the above-elbow and shoulder-disarticulation subjects. Similarly, the activities that are most difficult for below-elbow subjects also present the greatest difficulty for above-elbow and shoulder-disarticulation amputees. Not readily explained is the fact that the activities for which the prosthesis is apparently most useful generally rank low in frequency of occurrence or importance or both, while activities for which the prosthesis is least useful generally rank high in occurrence and importance.

Old Versus New

Table 20 compares reports by unilateral arm amputees as regards the extent of use of the old and the new prostheses. It reveals a consistent but by no means universal trend

Table 19

INDEX OF USEFULNESS OF PROSTHESES AMONG UNILATERAL ARM AMPUTEES[a]

(Percentage of Amputees Using Prosthesis Every Time Occasion Arose)

Activity	Amputee Type		
	Below-Elbow (N = 168)	Above-Elbow (N = 158)	Shoulder Disarticulation (N = 23)
1. Sharpen pencil	90	76 (2)	61 (4)
2. Carry several packages	89	85 (1)	87 (1)
3. Use "Flit" gun	85	73 (3)	22 (14)
4. Carry cafeteria tray	85	55 (9)	52 (6)
5. Rewire electric plug	83	73 (3)	52 (7)
6. Use paper clip	83	67 (5)	70 (2)
7. Use hammer and nails	83	65 (6)	65 (3)
8. Put on glove	82	60 (8)	39 (11)
9. Sweep up dirt with brush and dustpan	79	54 (10)	61 (4)
10. Take bills out of wallet	76	53 (11)	43 (10)
11. Use can or bottle opener	76	49 (13)	39 (12)
12. Assist someone with coat	75	28 (17)	0 (20)
13. File and clean fingernails	74	61 (7)	52 (7)
14. Tie shoelaces	73	38 (16)	9 (17)
15. Open bottles, jars, and tubes	72	50 (12)	48 (9)
16. Tie necktie	67	47 (14)	17 (15)
17. Unbutton shirt sleeve	61	25 (19)	4 (19)
18. Play cards	59	41 (15)	17 (15)
19. Cut food with knife and fork	52	20 (20)	9 (18)
20. Use telephone (particularly when taking notes)	40	27 (18)	26 (13)

[a] Activities are ranked in descending order of usefulness to below-elbow amputees. Numbers in parentheses give corresponding rank for above-elbow and shoulder-disarticulation subjects.

toward greater utilization of the new prosthesis as compared with the old. It is most apparent in the above-elbow subjects (increase for 17 of the 20 activities), less apparent in the below-elbow and shoulder-disarticulation amputees. As regards specific activities, however, there appears to be no systematic pattern of changes in degree of prosthetic utilization, and hence the general evidence here is rather inconclusive.

Reasons for Performing Activities Without Using the Prosthesis

In the foregoing material, consideration has been given to the matter of amputee utilization of prostheses in terms of their use always, sometimes, or never in performing each of the 20 activities under study. When an amputee always uses his prosthesis in the performance of a particular activity, some degree of adequacy of the limb for that task may be assumed. When, however, he "sometimes" performs a task without using his prosthesis, or when he "never" uses the artificial arm in the performance of that activity, prosthetic inadequacy to some degree would seem apparent. An understanding of the specific inadequacies of today's arm prostheses with respect to each of the 20 activities would be of great value in prescription and training as well as in planning research. Accordingly, each amputee who indicated less than full utilization of his prosthesis in a given activity was asked why he didn't use his prosthesis every time he had occasion to perform that task.

The most specific, although not the most frequent, reason given for not using the

Table 20

EXTENT OF PROSTHETIC USE, OLD *VS.* NEW ARMS

(Percentage of Unilateral Amputees Reporting That They Always Use the Prosthesis)

Activity	Amputee Type					
	Below-Elbow (N = 168)		Above-Elbow (N = 158)		Shoulder Disarticulation (N = 23)	
	Old Arm	New Arm	Old Arm	New Arm	Old Arm	New Arm
1. Cut food with knife and fork	43	52	9	20	13	9
2. Sharpen pencil	79	90	52	76	39	61
3. Sweep up dirt with brush and dustpan	84	79	44	54	13	61
4. File and clean fingernails	69	74	66	61	30	52
5. Tie necktie	62	67	40	47	74	17
6. Use telephone (particularly when taking notes)	24	40	12	27	30	26
7. Assist someone with coat	75	75	38	28	13	0
8. Take bills out of wallet	80	76	43	53	39	43
9. Unbutton shirt sleeve	64	61	13	25	0	4
10. Carry several packages	91	89	73	85	100	87
11. Use "Flit" gun	77	85	56	73	0	22
12. Open bottles, jars, and tubes	61	72	31	50	52	48
13. Put on glove	79	82	55	60	26	39
14. Use paper clip	89	83	60	67	70	70
15. Carry cafeteria tray	81	85	32	55	52	52
16. Use can or bottle opener	53	76	29	49	26	39
17. Tie shoelaces	58	73	42	38	22	9
18. Play cards	51	59	37	41	43	17
19. Rewire electric plug	90	83	68	73	57	52
20. Use hammer and nails	81	83	49	65	57	65
Mean	69.5	74.2	42.5	52.4	37.8	38.7

prosthesis in the performance of particular activities was that the terminal device was inadequate. For instance, a given terminal device might be capable of holding a wallet or taking out bills but be ill-suited for holding a fork; it might be suitable for holding a necktie but not for handling a telephone. It may therefore be concluded that one major reason for not using the prosthesis in performing certain activities relates to lack of versatility in the terminal device.

Another important reason advanced for failure to use the prosthesis was that the terminal device could not be brought to the appropriate functional position and operated there. Although the exact cause of this difficulty is not apparent from the data, it may be related directly to prosthetic inadequacies. As a matter of fact, not many amputees were able to give clear reasons for not using the prosthesis, so that it is possible only to speculate on the implications of the responses Some subjects stated simply that they "could not perform" the task in question. Since this kind of response may indicate either lack of training or genuine prosthetic deficiency or both, full interpretation requires further investigation. In the absence of a more complete examination, it may only be guessed that poor features in the available prosthetic equipment contributed in some way to its disuse.

That an activity was "easier to perform without the prosthesis" was the reason given most frequently for failure to use an artificial arm. Although not especially revealing, such

statements reaffirm the conclusion reached for other aspects—that for numerous amputees performance of certain activities presents such difficulty that it is "cheaper" in time, effort, and peace of mind to do without the prosthesis. A sharp rise in the number of "easier-without-prosthesis" responses was noted in the above-elbow amputees as compared with the below-elbow subjects—a result in keeping with earlier findings of decreasing prosthetic usefulness at the higher levels of amputation.

A number of amputees reported that the prosthesis was not worn at the time a particular activity was performed. This circumstance may be considered as indicating either that the activity was easier to perform without the prosthesis or that performance without the prosthesis presented no particular problems. Were the prosthesis indispensable, it would be worn on almost all occasions when opportunity to perform the listed activities arose. Since it evidently was not, it must be assumed that some amputees could dispense with their prostheses without (to them) significant functional loss.

Two other general observations can be made concerning the reasons for nonuse of the prosthesis. Both reinforce evidence presented earlier. One is that the number of "reasons" for nonuse of the prosthesis increased sharply for the above-elbow group as compared with the below-elbow subjects, which is only to say that more above-elbow amputees than below-elbow amputees report "sometimes" or "never" as regards use of the prosthesis. The other is that some "important" activities and some "occurring frequently" (such as cutting food, tying a necktie, using a telephone, taking bills out of a wallet, unbuttoning the shirt sleeve, tying shoelaces, and so on) are also reported by many amputees as being easier to perform without the prosthesis than with it.

In summary, it would appear that in general the statements made by all amputee groups point, either directly or by implication, to functional inadequacies of the prosthesis as the basic reason for failure to make full use of it. The specific inadequacies, and the means of correcting them, are of course not directly or fully revealed by the present data. Even the seemingly straightforward problem of inadequate prehension in terminal devices cannot be solved simply by adding rubber bands or by providing a device with a stronger grasp. Experience has shown that for numerous amputees a lightly loaded hook is adequate for most needs and that they therefore prefer it. They object to the necessity for overcoming heavy resistance in every operation just to accommodate needs occurring infrequently. Nor is the voluntary-closing hook always the answer. Evidence presented in Section V of this series shows that such voluntary-closing devices as are currently available also are not without objectionable features. The solution of such problems must await further research into the total area of prosthetic utilization.

Manner of Performing Activities Without the Prosthesis

When, in a particular activity, an amputee regards the use of the prosthesis as either impossible or too difficult, awkward, or time-consuming, he is faced with the choice of excluding the activity from his routine of living or of finding some substitute means of accomplishing it. In the NYU Field Studies, those subjects who did not use the prosthesis in one or more of the 20 selected activities were asked what they did when confronted with the task or tasks concerned. By far the most frequent response by all classes of unilateral arm amputees was to the effect that they used the remaining hand, either alone or in combination with some other part of the body or some external object. About ¾ of all responses told of one-handed performance, and the activities which are normally bimanual but for which performance was actually one-handed were essentially the same ones for all three classes of unilateral amputees. Moreover, activities so performed were for the most part the same ones as those reported to be "easier to perform without using the prosthesis" and also the same as those said to be most difficult to perform with a prosthesis (*i.e.*, least facilitated by assistance from a prosthesis).

A second alternative to use of the prosthesis, occurring in about 10 percent of the responses,

was the use of substitute devices such as combination knife-forks, telephone holders, or playing-card holders—all simply aids to one-handed performance. As for other methods of accomplishing daily tasks without use of a prosthesis, some 15 percent of the subjects indicated that the services of another person were enlisted. Again, as in the case of one-handed performance, the activities most frequently cited were much the same ones for all three groups of unilateral amputees. Although there is no apparent reason behind the choice of activities for which outside help is to be sought, it is possible that the tasks selected are too difficult to perform alone, either with or without a prosthesis. But of course other factors—an overly solicitous wife, general dependency, lack of training—may well be involved.

Two important goals in upper-extremity prosthetics are to help the amputee be independent in the performance of the tasks of daily living and to permit him to function bimanually in as "normal" a fashion as possible. Obviously the final achievement level may be below that of a "normal" person, but nevertheless these goals remain the best standard of comparison. Prosthetic utilization may be viewed as ranging from an optimum of complete independence and bimanual function to less independent performance with the sound arm alone, either with or without assistive devices, to a complete dependence on assistance from others. The employment of this scale of achievement along with additional measures of the *quality* or appearance of prosthetic performance should provide a useful basis for evaluating the degree of success obtained in amputee rehabilitation.

From the material here presented, we may conclude that, in the 20 selected tasks, the most common substitution for prosthetic use involves use of the remaining "good" hand, either alone or in combination with some other part of the body or some external object. One-handedness, with or without the use of substitute devices, avoids the necessity of dependence on others, but it also leaves much to be desired from the standpoint of simulating "normal" performance. Moreover, one-handed performance of such activities as tying a necktie, or unbuttoning shirt sleeves with the teeth, is not easy. If these methods really are "easier" without a prosthesis, then prosthetic use must indeed be unattractive to the individuals concerned. The general findings of the whole study lead, however, to the obvious conclusion that a prosthesis is at best only a partial replacement for a lost limb. In unilateral arm loss, increased usage of the remaining arm and hand has unavoidably to make up, to greater or lesser degree, for existing prosthetic inadequacies.

BILATERAL SUBJECTS

As already pointed out (page 49), the 10 bilateral subjects in the Upper-Extremity Field Studies included 7 bilateral below-elbow and 3 bilateral below-elbow/above-elbow cases. Undoubtedly, the general performance level of the group as a whole was higher than it would have been had the sample included bilateral above-elbow and bilateral shoulder-disarticulation subjects. The extent of prosthetic utilization exhibited must therefore be interpreted accordingly. The responses of the subjects concerning frequency of occasion to perform the 20 selected activities, importance of the selected tasks, and frequency of actual prosthetic performance are presented in Tables 21, 22, and 23.

Frequency of Occasion to Perform Activities

Table 21 presents the responses of the bilateral subjects as to the frequency of occasions for performing the 20 selected activities with prostheses. It will be apparent at once that the activities for which opportunity occurred to the majority of bilateral amputees daily were for the most part the same ones occurring most frequently for unilateral subjects.

Importance of the Activities

The ratings of the bilateral group as to the significance of the 20 activities are presented in Table 22. On the basis of a composite of the two ratings "very important" and "important," the activities most significant to the bilateral amputees were, with the single exception of sweeping up dirt, the same ones

Table 21

FREQUENCY OF NEED FOR BILATERAL ARM AMPUTEES TO PERFORM ACTIVITIES
PERCENTAGE OF AMPUTEES RESPONDING
(N = 10)

Activity	Frequency			
	At Least Once Daily	At Least Once Weekly	At Least Once Monthly	Less Than Once Monthly or Never
1. Cut food with knife and fork	90	0	0	10
2. Sharpen pencil	20	70	10	0
3. Sweep up dirt with brush and dustpan	10	70	10	10
4. File and clean fingernails	[a]	[a]	[a]	[a]
5. Tie necktie	40	20	10	30
6. Use telephone (particularly when taking notes)	60	10	30	0
7. Assist someone with coat	20	20	30	30
8. Take bills out of wallet	80	0	0	20
9. Unbutton shirt sleeve	50	10	0	40
10. Carry several packages	40	50	0	10
11. Use "Flit" gun	0	0	40	60
12. Open bottles, jars, and tubes	70	0	10	20
13. Put on gloves	[a]	[a]	[a]	[a]
14. Use paper clip	40	0	40	20
15. Carry cafeteria tray	10	0	40	50
16. Use can or bottle opener	70	10	0	20
17. Tie shoelaces	50	10	10	30
18. Play cards	10	20	20	50
19. Rewire electric plug	0	0	10	90
20. Use hammer and nails	10	10	20	60

[a] Not applicable.

that rated high in importance for the three unilateral groups, and more than half of these were among the ones occurring most frequently. Thus the general pattern of relationship between frequency and importance observed with the unilateral groups appears to apply to the bilaterals also. And again, as with the unilateral cases, the activities of bilaterals that apparently do not conform to this pattern give rise to speculation. A case in point is the matter of using the telephone. Ostensibly an activity which confronts bilateral arm amputees rather infrequently (Table 21), it is rated as significant by all of the ten subjects involved. Either the activity is considered important in spite of infrequent occurrence or, more likely, bilateral amputees avoid use of the telephone because of difficulty in handling it with their prostheses. Avoidance could explain infrequent occurrence.

Performance of Activities

Table 23 summarizes the responses of the 10 bilateral amputees as regards utilization of the program prostheses in the performance of the 20 selected activities. The always-or-never characteristic of prosthetic utilization, described earlier for unilateral amputees, is even more evident in the bilateral group. At Evaluation II, only one bilateral amputee reported "sometimes" use of the prostheses in any of the 20 activities. Judging from the proportion that never perform a given activity, the tasks that are the most difficult for bilateral amputees are also among those occurring most frequently for them, or rated most important by them, or both, so that the situation noted earlier for unilateral subjects again applies to bilaterals also. If we take as a basis of comparison the percentage of bilateral arm amputees who always use the prostheses to perform

Table 22

SIGNIFICANCE OF ACTIVITIES TO BILATERAL ARM AMPUTEES

PERCENTAGE OF AMPUTEES RESPONDING

(N = 10)

Activity	Importance		
	Very Important	Important	Little or No Importance
1. Cut food with knife and fork	70	20	10
2. Sharpen pencil	20	20	60
3. Sweep up dirt with brush and dustpan	10	40	50
4. File and clean fingernails	[a]	[a]	[a]
5. Tie necktie	20	30	50
6. Use telephone (particularly when taking notes)	60	20	20
7. Assist someone with coat	0	50	50
8. Take bills out of wallet	70	20	10
9. Unbutton shirt sleeves	30	10	60
10. Carry several packages	40	50	10
11. Use "Flit" gun	0	10	90
12. Open bottles, jars, and tubes	40	30	30
13. Put on gloves	[a]	[a]	[a]
14. Use paper clip	0	50	50
15. Carry cafeteria tray	20	20	60
16. Use can or bottle opener	50	20	30
17. Tie shoelaces	50	20	30
18. Play cards	0	40	60
19. Rewire electric plug	0	30	70
20. Use hammer and nails	20	30	50

[a] Not applicable.

an activity, then as a group bilaterals use their prostheses more extensively than do any of the unilateral groups. The comparative figures, including the apparent anomalies, lead to the logical supposition that, if they can, bilaterals will perform the most difficult tasks in order to be independent but that some tasks may be too complex for them to manage in spite of a strong desire to do so.

Reasons for Not Using the Prosthesis and Alternative Ways of Performing Activities

Because of the small number of cases involved, and because of the variety of body movements used by bilateral arm amputees to accomplish tasks without prostheses, a detailed analysis of substitution techniques is not warranted, but two general observations may be made nevertheless:

1. Prosthetic deficiencies related to nonperformance were concerned with inadequate grasp by the terminal device and inability to operate it at the appropriate level.

2. The chief remedy for such deficiencies was to have someone else perform the task. Use of substitute devices was confined largely to unbuttoning shirt sleeves, presumably by use of a special buttonhook held in a prosthesis.

DISCUSSION

The NYU Field Studies reveal a number of interesting highlights regarding the utilization of prostheses reported by upper-extremity amputees. With only minor exceptions, the 20 bimanual activities, chosen empirically, occurred in every case with sufficient frequency, and/or affected a large enough proportion of the amputee population, to be considered significant. Among the various amputee groups (unilateral below-elbow, above-elbow, and shoulder-disarticulation cases and bilateral arm cases) there was considerable agreement as to the relative frequency of occurrence of the activities. It must also be noted, however, that among the bilaterals the frequencies of occurrence were much lower than among the other groups. For example, only 10 percent of the bilaterals carried a cafeteria tray as often as once a week, and none of them used a "Flit" gun or rewired an electric plug as often as once a week. Finding such agreement supports the selection of these activities as being highly significant in the activity patterns of upper-extremity amputees.

As judged by amputee opinions concerning the importance of the 20 selected activities, the level of significance attached to the individual tasks varied considerably. For unilateral subjects, 10 of the activities were rated as important by $\frac{2}{3}$ or more of the group, five were rated as important by $\frac{1}{3}$ to $\frac{1}{2}$, and five were significant to less than $\frac{1}{3}$. For the bilateral group, 11 activities were rated as important by $\frac{2}{3}$ or more of the sample. For all amputee types, even those activities rated as important by the least number of amputees could not be regarded as totally insignificant. On the basis of amputee judgments of frequency of occurrence and of importance,

Table 23

USE OF NEW PROSTHESES BY BILATERAL ARM AMPUTEES IN THE PERFORMANCE OF SELECTED ACTIVITIES
PERCENTAGE OF AMPUTEES RESPONDING
(N = 10)

Activity	Use of New Prostheses			
	Always	Sometimes	Never	No Occasion to Perform Activity
1. Cut food with knife and fork	60	10	20	10
2. Sharpen pencil	100	0	0	0
3. Sweep up dirt with brush and dustpan	90	0	0	10
4. File and clean fingernails	[a]	[a]	[a]	[a]
5. Tie necktie	40	0	30	30
6. Use telephone (particularly when taking notes)	100	0	0	0
7. Assist someone with coat	100	0	0	0
8. Take bills out of wallet	80	0	0	20
9. Unbutton shirt sleeve	10	0	40	50
10. Carry several packages	100	0	0	0
11. Use "Flit" gun	40	0	0	60
12. Open bottles, jars, and tubes	60	0	10	30
13. Put on gloves	[a]	[a]	[a]	[a]
14. Use paper clip	70	0	10	20
15. Carry cafeteria tray	70	0	10	20
16. Use can or bottle opener	70	0	10	20
17. Tie shoelaces	40	0	30	30
18. Play cards	50	0	0	50
19. Rewire electric plug	20	0	0	80
20. Use hammer and nails	50	0	20	30

[a] Not applicable.

therefore, the tasks selected appear to have constituted a sound basis for study of the patterns of prosthesis usage among arm amputees. Although significant exceptions were apparent, in general the activities occurring most frequently were also rated as the most important.

In sum, the data on amputee use of prostheses in performance of the 20 selected activities revealed a number of interesting, if occasionally unexpected, findings. Among these were:

1. *A sharp drop-off in prosthetic utilization from below-elbow to above-elbow to shoulder-disarticulation amputees, found in an earlier investigation* (page 32), *was confirmed.* While over-all utilization of the prosthesis by all amputee types, including the above-elbow and shoulder-disarticulation cases, was quite remarkable, improved utilization was most striking among the below-elbow and bilateral amputees. More than 50 percent of all unilateral below-elbow subjects reported that they always used the prosthesis in the performance of 19 out of the 20 selected activities (Table 18), and at least half of the bilateral amputees reported 100-percent use in 13 out of 18 applicable activities (Table 23).

Because heretofore prostheses for above-elbow and for shoulder-disarticulation amputees have sometimes been regarded as comparatively useless, the data relating to these types of amputees are perhaps even more dramatic than are the corresponding results for the other two types. In the above-elbow group, 50 percent or more of the sample reported that for widely diverse tasks they always used the prosthesis. In a number of "important" activities, a smaller but still significant proportion of above-elbow subjects always used the prosthesis. If we focus attention on what was *done* rather than on what was *not* done, there is considerable evidence that the prostheses had real value even for the shoulder-disarticulation group. Some 50 percent or more of the sample reported that in performing 8 of the 20 tasks they always used the prosthesis. In almost none of the activities could the prosthesis be considered useless. Even for the shoulder-disarticulation amputee, to whom a prosthesis offers the least

functional replacement, the fitting and use of a modern artificial arm seems worth while. And a similar conclusion may be drawn from the data presented earlier concerning use of the prosthesis in eating, dressing, and vocational, recreational, and home activities by all classes of amputees, including above-elbow and shoulder-disarticulation cases.

There are, then, two sides to the coin of prosthetic usefulness. One points to the inadequacies of even the most up-to-date equipment and emphasizes the need for much improvement. The other shows that, despite prevailing inadequacies, present-day upper-extremity prostheses are quite useful devices, particularly in those cases once thought incapable of deriving much benefit from any arm substitute.

2. *An "all-or-none" type of phenomenon in amputee use of prostheses was noted.* In any given activity, an amputee tends either always to use his prosthesis or never to use it. While not absolute or universal, the inclination was considered strong enough to be viewed as a general characteristic of prosthetic utilization.

3. *Paradoxically, the prosthesis was most useful for many activities which occurred less frequently, or which amputees rated as less important.* Some of the more frequently occurring, and more important, of the 20 activities, such as "cut food with knife and fork" and "unbutton shirt sleeve," were less frequently performed with the prothesis. This may indicate that the difficulty of performing the task with prothesis influences frequency of prosthetic use more than does the frequency of occasion for use or the importance of the task.

4. *Although there were definite indications that the program prostheses were used more extensively than were their preprogram counterparts, the increase in utilization was neither universal nor particularly striking.* The reasons given by arm amputees for not using their prostheses in the performance of activities pointed generally to prosthetic inadequacies as the basic cause. While lack of a suitable all-purpose terminal device was the only specific item identifiable from the data, it appears that the whole area of amputee use or nonuse of an arm prosthesis calls for further and intensive study. Where arm amputees did not use their prostheses in activity performance, the most common substitution among unilateral subjects involved use of the remaining hand, either alone or in combination with some other part of the body or some external object. One-handedness replaced what would normally be bimanual performance. Among bilateral arm amputees, "someone else does it for me" was the most frequent compensation for failure to use prostheses.

In the final analysis, the value of any particular set of principles or procedures in upper-extremity prosthetics is reflected by the degree of acceptance and utilization afforded the wearer by the prosthesis after the novelty has worn off and routine operation is expected. As part of the NYU Field Studies, therefore, the opinions of a large and diversified group of arm amputees were obtained on widely separated occasions in response to a series of open-end and multiple-choice questions relating to five key areas of activity considered more or less common to all persons. These reactions, classified and analyzed in terms of amputation type, were augmented by interviewing the same group of subjects with regard to 20 bimanual activities selected empirically as being important and of frequent occurrence in the course of daily living.

These two inductive approaches were selected from many possibilities for investigation as being the most practical and appropriate for determining amputee opinions as regards the utility and general value of their prostheses. Though the answers obtained do not provide a completely definitive method for grading success or failure in the rehabilitation of arm amputees, they have nevertheless furnished much useful information on a number of the factors influencing acceptance of prostheses by their wearers.

As might have been anticipated, amputees with the more disabling conditions (that is, with higher levels of amputation) were able to employ their prostheses over a smaller range of activities. On the other hand, the greatest increases in prosthetic utilization were found among these very groups. Not anticipated, however, was the indication that, in general, amputees tend to use their prostheses every time they do a given activity or not at all. The frequency of occurrence and the importance of an activity to an amputee were not always indices of the utility of the prosthesis in the particular task. While there were definite improvements in the utilization of program prostheses, a great deal of room for improvement remains, particularly in the bilateral group. Although deficiencies in the prostheses may be responsible, other factors such as training and motivation may also be involved. New studies focused on these questions will be required to illuminate the specific relationships.

Part 2
Amputee Performance With Arm Prostheses

Since arm amputees, like most people, are not generally capable of a completely realistic self-appraisal, there is an inherent weakness in data which derive solely from verbal reports. For this reason, a second method of evaluation was devised with the purpose of assessing prosthetic use on the basis of more objective information. Based on the assumption that proficiency in use also reflects the value of the prosthesis to the amputee, two types of prosthetic proficiency tests were developed. The first was designed to measure the amputee's skill in prehension and accuracy in positioning the terminal device for prehension. The second was concerned with evaluating skill in performing a series of common daily activities.

TEST RATIONALE AND TEST DEVELOPMENT

Methods of evaluating human performance in physical activities vary from the simple, relatively objective timing of a footrace to the more subjective assessment of figure-skating or fancy diving. In the footrace, effectiveness of performance is determined solely by measuring time, since speed of performance is the main factor. In rating activities of the second type, consideration also is given to such subjective features as timing, rhythm, grace, and form because here both effectiveness and appearance are matters contributing equally to the overall result. Since the total value of performance with a prosthesis involves these two factors, efforts to analyze the quality of prosthetic use in the NYU Field Studies sought information not only on the effectiveness with which the amputee used his prosthesis in activities of daily living but also on his appearance while performing them. In this sense, "effectiveness" refers to the ability to complete a task in a reasonable time. "Appearance" has to do with the relationship between the performance of the amputee and that typical of a normal person.

ABSTRACT-FUNCTION TESTS

Considering the uses arm amputees make of the various functions provided by modern arm prostheses, it is clear that all artificial arms are employed primarily as prehensile tools. But the ability to grasp with a hook or artificial hand would be extremely limited were the terminal device restricted to one plane or to a single area of operation. The value of other prosthetic functions, whether passively or actively controlled, lies in their usefulness as a means of positioning the terminal device so that work can be performed throughout a large operating sphere. It may reasonably be said that all the motions that can be provided in an upper-extremity prosthesis are capable of classification into one of two functional categories—those involved in the act of prehension itself and those which are used to position the terminal device so that meaningful prehension may be performed. Recognition of these functional divisions led to the development of two tests of abstract function—the prehension test and the positioning test—designed to permit study of some of the factors involved in prehension and positioning. They are tests of "abstract function" in the sense that no purposeful activity is involved and that only the biomechanical functions of positioning and operating the terminal device are analyzed.

Tests of abstract function were, then, used to assess the amputee's ability to:

1. operate and control his terminal device in grasping, transporting, and releasing objects.
2. position his terminal device accurately and operate it effectively in various places in front and to the side of his body.

PRACTICAL-ACTIVITIES TESTS

Tests of practical activities, used in an evaluation of *how* the amputees performed meaningful activities of daily living, were designed to provide information concerning the facility and appearance of a total performance in order to measure the functional value of the appliance. Selection of the performance tests of practical function was based on three prime criteria—that the activities concerned should normally require

bimanual performance, that the activities concerned should be those performed frequently by the subjects being tested, and that performance of the activities should be important to the amputee.

Tests of practical function were, then, used to rate:

1. the effectiveness with which amputees perform common, everyday tasks.
2. the naturalness of appearance while amputees perform daily activities.

STANDARDS OF PERFORMANCE

In the choice of a yardstick with which to measure the quality of prosthetic performance, consideration was given to the purpose of fitting an amputee with an artificial arm. Since the obvious aim is to restore as much as possible of the function lost through amputation, the desired outcome is that the amputee accept and use his prosthesis as naturally and as "normally" as possible. For this reason, normal, two-handed performance of tasks appeared to be a valid criterion. Because, however, it is commonly recognized that an amputee can never attain a completely normal, two-handed pattern of performance, it may reasonably be objected that such a standard is to some degree unrealistic and that the rating of amputee performance in relation to that of other amputees would provide a more reliable comparison. Perhaps it would. But the absence of norms or standards of amputee performance at the time the NYU Field Studies were undertaken precluded any choice in the matter. Consequently, the normal performance pattern was selected as the standard.

Sample

The numbers of below-elbow, above-elbow, and shoulder-disarticulation amputees available for these performance tests varied considerably. Participating in the pretreatment tests were 80 below-elbow amputees, 57 above-elbow amputees, and 4 shoulder-disarticulation amputees representing, respectively, 48 percent, 36 percent, and 17 percent of each amputation type in the sample. Attrition during the pretreatment evaluation was due to nonfunctioning or malfunctioning of arms, amputees appearing for evaluation without prostheses, and breakdown of prostheses during use with consequent inability to complete the test. Owing to the generally better functional condition of arms during the course of the program and to the increase in the number of shoulder-disarticulation and above-elbow amputees wearing arms, the number of subjects available for post-treatment testing was substantially higher: 115 (68 percent) below-elbow, 111 (70 percent) above-elbow, and 17 (74 percent) shoulder-disarticulation cases. To provide the most rigorous analysis that the data will permit, only the performances of the patients available for both pre- and post-treatment evaluations are presented. This restricts the total sample to 75 below-elbow, 51 above-elbow, and 4 shoulder-disarticulation cases. Because there are so few shoulder-disarticulation amputees, their performance ratings are not treated statistically but are described in terms of impressions and trends.

All of these amputees took the prehension test, the first to be administered, but somewhat fewer completed the positioning test and the practical-activities tests, either because of breakdown of prostheses during the course of the tests or because of indisposition on the part of the patients.

Procedures

ABSTRACT-FUNCTION TESTS

Prehension Test

In utilizing his prosthesis in the activities of daily living, the amputee has occasion to grasp objects of various sizes, shapes, weights, textures, and degrees of fragility or hardness. This diversity was recognized by including, in the prehension test, objects which embody many of the variables normally encountered. Of the 12 objects used, six were of metal (five aluminum, one steel) and six of compressible rubber, and all were of one of four

basic shapes—cylinders, spheres, prisms, and right-angled forms—in various sizes.

In addition, the testing materials included a form board constructed of "Masonite" attached to a three-ply wooden board measuring 17 × 17 in. and into which were cut recesses corresponding to the shapes of the test objects but slightly (1/8 in.) larger. The test objects were arranged on a table near the board and in the same relative position as the recesses in the board so as to reduce the need to search for the proper recess. In the course of the test, the amputee transferred each of the objects from the table to the appropriate recess in the form board. Before the actual test, the amputee was given a trial run to familiarize himself with the objects and to give him an opportunity to decide upon the most efficient way to approach and grasp an object. The test was explained to the amputees as follows:

"You are to place each of these objects in the appropriate recess in the form board. Start with the top row and work from left to right. Do each row in the same way.

"Work as quickly as you can but also as accurately and neatly as you can; do not waste any time.

"If you cannot handle any object after trying for 1 minute, leave it and go on to the next. You will be notified when you have been on any object for 1 minute.

"Use only your prosthesis in handling the various objects.

"Avoid compressing or distorting the shape of the rubber objects as much as possible.

"You are being tested on your ability to grasp the objects and to release them into the recesses in the form board."

In the performance of these tasks, the terminal device is first brought into a position which allows for grasp of the object. The next step, concerned with the grasp itself, involves operation of the prehension mechanism, placement of the fingers to obtain a stable grasp, and control of finger pressures to provide appropriate prehensile forces. To complete the activity, the amputee must transport the object and then position the terminal device so that the object is released at the intended place. The general impression that an amputee's performance makes upon the observer depends upon the body move-

ments employed, the number of errors made, and the appearance of the control motion. In addition to these factors, the appearance of the total performance is related to the general ease, grace, and accuracy of movement.

In an attempt to appraise in each activity both the functional and the appearance value of the amputee's performance, the significant parts of the performance were rated with regard to positioning movements for grasp and release, appearance and effectiveness of control motion, and control of finger pressure. The ratings were then combined in an over-all score on the basis of the following 10-point scale:

Excellent (10). Graceful, rhythmic, fast, accurate performance closely approximating the cosmetic value of a performance by a normal person.

Good (8). Smooth, rapid performance involving one or two errors and some slight body and limb distortion in several positions.

Average (6). Uneven, somewhat inaccurate performance with occasional errors, some effort, and some body distortion.

Fair (4). Slow performance marred by errors and uncosmetic limb and body positions.

Poor (2). Awkward, strained, slow performance with fumbling, excessive movement, and many errors.

The observer interpolated ratings of 9, 7, 5, 3, and 1 when indicated.

The ability of the arm amputee to grasp and hold objects securely with a prosthesis is dependent partly upon the amount of power the man-machine combination can furnish and partly upon the structure, size, and shape of the terminal device. The number of errors made during the test was recorded, two kinds of errors being considered—grasp errors and compression errors. A grasp error was counted when the amputee regrasped an object in an attempt to obtain a more secure grasp, when the object, once grasped, fell from between the fingers of the terminal device, or when the object slipped within the fingers to the extent that the amputee had to reduce his speed or otherwise interrupt his performance to avoid dropping it. The ability to control finger pressure was appraised by tallying the number of compressible objects distorted and judging the extent of the distortion.

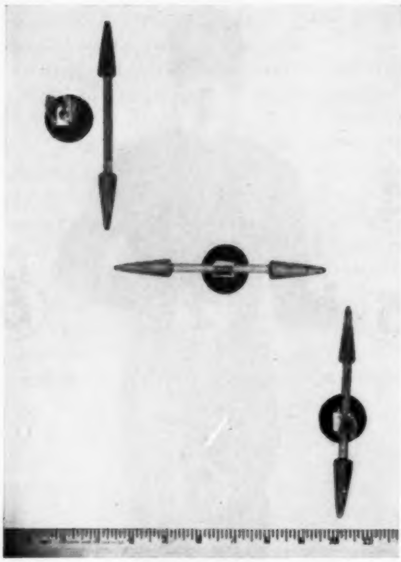
Considered alone, the time taken to perform a particular activity may not be a satisfactory indication of efficiency. When considered in relation to accuracy and appearance, however, it may be an important factor, particularly in view of frequent amputee complaints regarding inability to work rapidly. In the prehension test, the amputee stood at the table and began at his own volition, a stopwatch being started with his first movement. The watch was stopped as the last object was placed in the appropriate recess on the form board, and the elapsed time was recorded.

Positioning Test

Although prehension may be considered the primary function of both the normal hand and the prosthetic replacement, the ability to position the hand or its substitute in space is a key factor in utilization. The normal, two-handed person has occasion to reach for, grasp, and release objects in three planes. He commonly handles objects at the level of the mouth, the chest, and the mid-thigh, and objects at chest or waist level up to 1½ feet on either side of him are usually within his reach. To study the ability of the amputees to employ their prostheses in these areas, use

was made of the positioning test, which involved six common hand positions. The six exercises devised to assess the ability of an amputee to operate his terminal device at different positions required the subject to place a 6- × ⅜-in. dowel into a clip positioned on the wall and so arranged that release of the dowel was required in both vertical and horizontal positions. Before the actual tests, each amputee was given a trial run to familiarize him with the procedures and to let him decide upon the best approach to each of the test situations.

In the performance of this test, the amputee was required to remain within a rectangle drawn on the floor 18 in. wide and extending 36 in. from a wall. He stood outside this re-

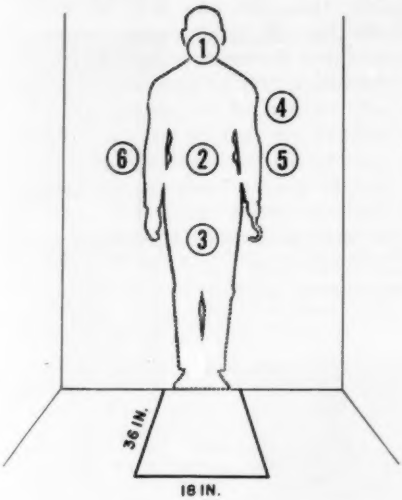


straining area until, on the signal to begin, he stepped into it. Although he was required to remain there while performing each of the tasks, he was permitted to reach over the restraining lines. The patient was told:

> "Hold this stick in your sound hand and stand behind the restraining line.
>
> "When I say 'go,' grasp the dowel in your prosthetic hand (hook), step into the restraining area, and place the dowel in the clip on the wall.
>
> "Do this as quickly as you can after you receive the signal, but do it as smoothly and as accurately as you can.
>
> "If you drop the stick while trying to place it in the clip, or at any other time, pick it up and continue the test.
>
> "You are being tested on your ability to place the stick in the clip as quickly as possible with the least amount of excessive movement."

Proficiency in this test depended upon maintaining a relatively normal posture and appearance while operating the terminal device at varying distances and angles from the body. The cosmetic value of the performance was related to ease, grace, and smoothness of body movements and to associated characteristics in prosthetic control motions, while effectiveness was reflected in the speed and accuracy of positioning the dowel in the clip. Rated individually were

body- and limb-positioning movements, appearance of prehension control motion, and appearance of elbow-lock control motion. These were then consolidated into a rating of total performance by use of the same type of 10-point scale as in the prehension test: excellent, 10; good, 8; average, 6; fair, 4; poor, 2. Again, ratings of 9, 7, 5, 3, and 1 were interpolated as necessary. The time required to perform each positioning test was recorded by means of a stopwatch.



PRACTICAL-ACTIVITIES TESTS

The practical-activities tests called for each amputee to be tested in the performance of eight activities of daily living selected from the 20 common activities discussed heretofore. For each individual the activities varied in accordance with the criteria of frequency and importance previously mentioned (*i.e.*, each amputee was tested on the eight activities he reported as occurring most frequently in his routine of living). In choosing between activities of approximately equal frequency, those regarded by the subject as of greater importance were selected for test.

In the discussion of the temporal sequence of events during performance of the prehension test, it was pointed out that four phases of the performance could be isolated: the positioning movements for grasp, the grasp itself, the transporting of the object, and the positioning movements for release of the object. With one major exception, this breakdown served equally well as a guide to the more complex practical activities. Here, unlike the situation prevailing in the prehension test, the amputee must not only transport an object but must also make sure it arrives at a position where it can be used or manipulated purposefully. Moreover, the nature of the prehension test forced the amputee to pick up each object from the table without use of the sound hand, a feature that made it necessary to position the body and the prosthesis so that the object could be grasped with the terminal device. In routine practice, however, the amputee frequently picks up an object with his sound hand and places it in his terminal device, thus eliminating many of the positioning movements otherwise required for grasp.

With special reference to practical-activities tests, therefore, we may speak of "positioning movements for use," as distinct from "positioning movements for grasp or release," to mean the sequence of motions adopted by an amputee to bring an object into position for the performance of a useful task. Each activity was rated according to the normalcy of the pregrasp positioning movements, the security of the grasp, and the adequacy of positioning for use. The first two were scored on the same basis as in the prehension test; the degree of awkwardness in the positioning movements was rated and the number of errors tallied.

Positioning for use, however, refers to the manner in which an object is grasped as that relates to the intended manipulation or use of the object. For example, when the normal hand holds a telephone, both mouthpiece and receiver are positioned close to the face for ease and comfort in hearing and speaking. The artificial hand of an amputee may hold the telephone at some distance from the face, thus necessitating some undue amount of compensatory head-bending. Or the hearing end of the telephone may be held against the ear while the mouthpiece is at eye level rather

than mouth level. Errors such as these in positioning an object for use may be due either to faulty judgment on the part of the amputee or to limitations inherent in the prosthesis. Whatever the cause, the adequacy of positioning in relation to ultimate use was rated in terms of the deviation from normal position and of the degree of compensatory movement necessitated by the position of the object in the appliance. These scores were then combined in an over-all rating of the functional and cosmetic value of the amputee's performance in each activity. Rating was accomplished on a 10-point scale as follows:

Excellent (10). Object position does not deviate from position for normal use, nor are compensatory body and limb positions necessary.

Good (8). Object deviates slightly from position in which the normal hand would use it; slight deviations in body and limb positions may also be present.

Average (6). Object deviates somewhat from normal position, and some compensatory deviation in body or extremity position is necessary to use the object.

Fair (4). Object shows marked deviation from normal position for use and necessitates somewhat awkward body and limb positions to accomplish the task.

Poor (2). Object shows marked deviation from normal position for use, accompanied by strained, awkward, or obtrusive body and limb positions.

The observer interpolated ratings of 9, 7, 5, 3, and 1 whenever it was felt to be necessary.

In the accompanying annotated illustrations are depicted the materials, instructions, and procedures utilized in the administration of the 20 activities comprising the test series. Every time the amputee began one of the practical tests, he was first requested to perform the task in his customary way. He was told that the series of tests was a means of determining how he performed those tasks normally as part of his activity pattern. It was pointed out that he was being rated on how well he did the entire task regardless of the specific use he made of the prosthesis. The basis for rating the over-all appearance of the performance was the same as that for the prehension test, and the time taken to complete each test activity was recorded.

1. *Cut Food With Knife and Fork*
Subject was seated at small table set with fork on left and knife on right, regardless of side of amputation. Plate contained "meat and potatoes" of clay. Subject picked up knife and fork, cut three pieces of "meat," and replaced utensils on table.

2. *Sharpen Pencil*
Sharpener was mounted on wall at chest height. Pencil was placed on table to right of sharpener. Subject picked up pencil, sharpened it, and returned it to table.

3. *Use Can or Bottle Opener*
Can (or bottle) and opener were placed on table. Subject stood facing table. He opened can (or bottle) and returned opener to table.

4. *Sweep Up Dirt With Brush and Dustpan*
Subject stood facing table. Dustpan and brush were placed on table, "dirt" was put on floor about three feet from table, waste basket on floor next to "dirt pile." Subject grasped dustpan and brush, swept up dirt, put it into wastebasket, and returned props to table.

5. *Use Telephone*
Subject was seated at table. French phone was placed on table at right with pad and pencil. Subject removed phone, dialed number, wrote message, and returned phone to cradle.

6. *Use Nail File*
Subject was seated at table. Nail file was placed on table. Subject picked up file, filed both sides of nail on index finger, and returned nail file to table.

7. *Assist Someone With Coat*
Subject stood next to coat hung on hanger. He removed coat and held it up for another person to put on.

8. *Take Bills Out of Wallet*
Amputee stood near table on which was placed wallet containing paper currency. He picked up wallet, removed two bills, and, placing them on the table, closed the wallet and replaced it on the table.

9. *Unbutton Shirt Sleeve*
Amputee stood and unbuttoned shirt sleeve on his sound arm.

10. *Carry Several Packages*
Subject stood and picked up suitcase and prepared "packages." He carried them in both arms a distance of five steps and put them down.

11. *Use Spray Gun*
The amputee stood near a table upon which was placed a sprayer of the "Flit" variety. Amputee picked up sprayer and operated piston three times, once each toward the ceiling, straight ahead, and down at the floor. He then replaced gun on table.

12. *Open Bottle, Jar, or Tube*
Amputee was seated at table upon which was placed a jar. He picked up jar, unscrewed cap, and replaced both cap and jar on table.

13. *Put on Glove*
Subject stood at table, picked up glove lying upon it, and proceeded to don glove completely.

14. *Use Paper Clip*
Amputee was seated at desk upon which were placed three sheets of paper and a paper clip. He gathered up papers, clipped them together, and replaced sheaf on desk.

15. *Carry Cafeteria Tray*
Amputee stood at table upon which was placed tray loaded with two dishes, a cup, and a saucer. He picked up tray, walked five steps, and placed tray upon table.

16. *Tie Shoelaces*
Subject stood near chair and, on his own volition, remained standing and placed foot on chair or else sat in chair. He then tied bow in lace of one shoe.

17. *Play Cards*
Subject was dealt a hand of five cards while seated at table. He picked them up, fanned them out, and played three cards sequentially.

18. *Rewire Electric Plug*
Amputee was seated at table with screwdriver, plug, and short electric wire laid out before him. He picked up tool and connected wires to terminals.

19. *Use Hammer and Nails*
Amputee stood at table upon which were lying a block of wood, hammer, and a 2-in. nail. He picked up hammer and drove nail into block.

20. *Tie Necktie*
The patient started with a necktie tucked under his collar but untied. He tied the knot.

Results

RELIABILITY AND VALIDITY

Fundamentally a test is an instrument for measuring the extent or absence of a trait or attribute. To be most meaningful, test results must be both reliable and valid.

The reliability of tests which are scored by means of judgmental ratings depends upon the use of consistent standards in rating performances, and ordinarily precautions are taken to ensure a comparable frame of reference among the raters. During the course of these studies, the reliability of the raters' judgments was evaluated periodically and found to be reasonably satisfactory. A stringent statistical analysis at the completion of the studies (Appendix I) confirmed the reliability of the ratings on the abstract-function tests. But because too few practical-activity tests were scored by each rater, the reliability of the practical-activities ratings could not be assessed in the same way.

The validity of a test rests upon the degree to which it actually measures what it is designed to measure. Selection of the abstract-function tests was based upon an analysis of the functional requirements of prosthetic utilization, the skills involved being those necessary to operate the prosthesis under *any* circumstances. Since these tests were designed to evaluate proficiency of prosthetic use by direct measurement of meaningful performance with prostheses, they have a certain amount of face validity. The validity of the practical-activities tests appears to be self-evident, since the amputee's ability to perform a given task was in this case determined by having him actually perform it in the presence of the raters.

ABSTRACT-FUNCTION TESTS

Prehension Test

As might have been anticipated, the ratings of below-elbow and above-elbow cases in the prehension test clearly indicated that performance was related to amputation level. That is to say, the average below-elbow performance level was consistently better than above-elbow performance in both pre- and post-treatment evaluations (Table 24). An important point reflected by these data is that the discrimination of differences by the prehension test may be regarded as evidence supporting the validity of the test. Experience indicates that the below-elbow amputee generally accomplishes more with a prosthesis and performs in a smoother and easier way than does the above-elbow amputee. Since it distinguishes these two groups clearly, the prehension test may be said to measure those qualities which distinguish the adequacy of performance.

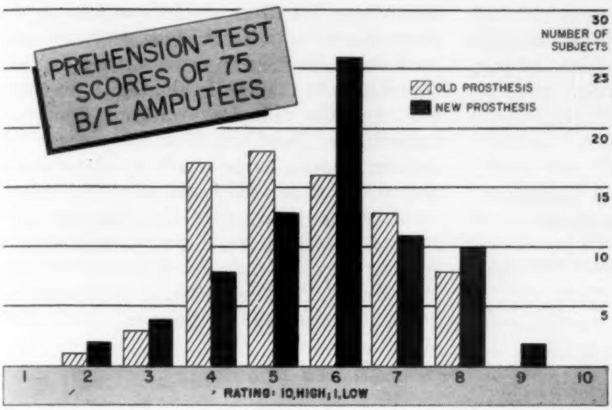
Table 24

Mean Performance Ratings and Standard Deviations in Prehension Tests

Amputation Level	Evaluation I		Evaluation II	
	MPR[a]	σ	MPR[a]	σ
Below-Elbow (N = 75)	5.5	1.5	5.8	1.6
Above-Elbow (N = 51)	4.0	2.0	4.9	1.5

[a] The significance of the differences between the mean ratings of below-elbow and above-elbow subjects at Evaluations I and II are given in Table 29 (page 80).

Comparison of performance ratings in the pre- and post-treatment evaluations, presented in Table 24, reveals a definite but not always statistically significant improvement in prosthetic function. For the 75 subjects comprising the below-elbow sample, the mean for the new arms was 5.8 as compared with 5.5 for the old. Although this difference is not significant statistically, closer study of the scores made at the two evaluations indicates a small but definite improvement in performance, especially through the middle of the score range, where there was a marked decrease in the number of amputees receiving ratings of 4 and 5 and a sharp increase in those receiving ratings of 6. It appears then that, although the treatment program had little effect on below-elbow amputees who exhibited very poor or very superior skills with their old



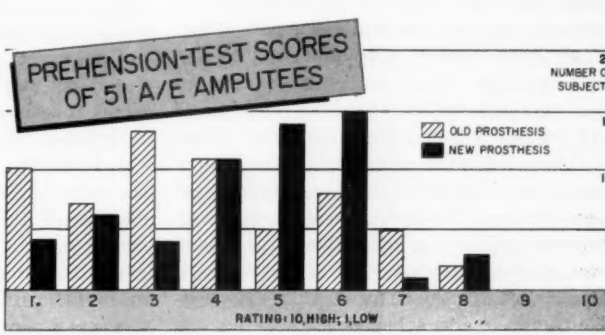
of above-elbow performance, the greatest improvement being evidenced among those of low and low-average skills. With only four cases available for analysis, the findings for the shoulder-disarticulation amputees are of limited significance, although among the four there was also a definite trend toward improvement in post-treatment performance.

In general, the results obtained in the functional tests of the above-elbow and shoulder-disarticulation amputees correspond to the verbal reports, which strongly indicated that the program prostheses were more useful, easier to operate, and more extensively used. Improvement in these two groups was more marked than in the below-elbow group, and it may therefore be concluded that the more severely handicapped segments of the amputee population derived the most benefit from the program prostheses and that the benefits accrued principally to the poorer performers.

The speed with which amputees performed the prehension test was also related to level of amputation, the below-elbow subjects taking significantly less time than the above-elbow cases to complete the test at both pre- and post-treatment evaluations. For no group (below-elbow, above-elbow, or shoulder-disarticulation) did the average amount of time

arms, it did improve the "low-average" performers.

As reported in Part 1 of this Section, the below-elbow group as a whole felt that their new arms were somewhat more useful and easier to operate than the old. But this improvement was less marked than that at other levels of amputation, and some below-elbow subjects even felt that the new prosthesis was inferior to the old. The data thus tend to corroborate an earlier conclusion that for the less severely handicapped below-elbow amputee the improvement in prehension skill was not outstanding. By contrast, the 51 above-elbow cases showed a decided improvement in prehension performance with the prostheses fitted in the Field Studies. Statistically, the 4.9 average achieved with the program prostheses was significantly higher than the 4.0 average attained with the old arms. A comparison of the scores at the two evaluations revealed a clear-cut and consistent shift in the direction of improvement of performance. There was a marked decrease in the number of amputees scoring below 5 and a sharp increase in those scoring above 5. It may therefore be concluded that there was a general elevation of the level



taken to perform the prehension test decrease significantly after treatment. The data for the below-elbow and above-elbow subjects are presented in Table 25.

Table 25
MEAN PERFORMANCE TIMES AND STANDARD DEVIATIONS IN PREHENSION TESTS

Amputation Level	Evaluation I		Evaluation II	
	MPT[a]	σ	MPT[a]	σ
Below-Elbow (N = 75)	130	60	127	56
Above-Elbow (N = 51)	174	76	180	97

[a] To nearest second.

According to these findings, improvement in performance skill was not reflected in an appreciable increase in performance speed, but the reasons for this apparent inconsistency are not clear. One possibility has to do with the increase in the number of subjects using APRL terminal devices at Evaluation II as compared with Evaluation I (below-elbow, from 14 to 37; above-elbow, from 8 to 31). The "double-shuffle" control motion involved in this type of device, and the consequent increase in the time required to operate it, may account for the failure to increase speed along with skill and ease of operation. At the same time, however, there is a suggestion that slower operation with APRL devices is accompanied by smoother and easier prehension.

Two kinds of errors, grasp and compression, were recorded. Grasp errors were counted when an object slipped or fell from the terminal device or when it had to be regrasped. Compression errors were scored when the rubber objects were distorted by poor control of finger pressure. On both pre- and post-treatment evaluations, the below-elbow cases made fewer grasp errors than did the above-elbow amputees (Table 26). The shoulder-disarticulation cases made substantially more grasp errors than did either the below-elbow or the above-elbow subjects. The below-elbow subjects made fewer grasp errors after treatment (average: 8.0) than at Evaluation I (average: 9.2), but the difference was not significant statistically. There was little difference in the number of grasp errors made by above-elbow amputees before (10.0) and after (9.7) treatment. While the shoulder-disarticulation cases showed a stronger trend toward improvement in grasp security than did either of the other two groups, the result should be interpreted cautiously because of the small number of subjects involved.

Table 26
MEAN NUMBER OF GRASP ERRORS AND STANDARD DEVIATIONS IN PREHENSION TESTS

Amputation Level	Evaluation I		Evaluation II	
	MGE	σ	MGE	σ
Below-Elbow (N = 75)	9.2	6.0	8.0	5.5
Above-Elbow (N = 51)	10.0	5.9	9.7	6.4

Thus it would appear that, despite the changes made in terminal devices, harnessing, and control-system alignment, grasp security was not greatly influenced by the treatment process. Perhaps the principal limitation was the lack of "all-purpose" versatility in the hook, its rigid structure preventing it from being completely suitable for handling a variety of objects.

Unlike grasp errors, compression errors decreased in frequency among both below-elbow and above-elbow cases after fitting with program arms (Table 27), and the shoulder-disarticulation amputees appeared to follow the same trend. Below-elbow and above-elbow cases made the same number of compression errors (6.2) in the pretreatment evaluations. After the treatment procedure, there was again little difference between the scores of the two groups, the averages being 4.5 and

4.8 respectively. As one would expect, the shoulder-disarticulation cases made more compression errors than did either below-elbow or above-elbow subjects.

Table 27

MEAN NUMBER OF COMPRESSION ERRORS AND STANDARD DEVIATIONS IN PREHENSION TESTS

Amputation Level	Evaluation I		Evaluation II	
	MCE	σ	MCE	σ
Below-Elbow (N = 75)	6.2	4.1	4.5	3.9
Above-Elbow (N = 51)	6.2	3.9	4.8	3.2

Better control of finger pressure may be explained by the large proportion of APRL devices fitted in the treatment program and also by the contributions from improved harness and control systems. The apparent influence of APRL terminal devices in improving control of finger pressure without also improving grasp security suggests a deficiency in hook size or shape and perhaps also a general lack of emphasis on training for the proper approach in prehension activities.

Positioning Test

Skill in performance in the positioning test, as in the prehension test, was related to level of amputation, the below-elbow amputees making consistently higher scores, and the positions in which the below-elbow subjects performed best differed from those in which the above-elbow subjects were most effective (Table 28). The below-elbow amputees were most effective at mouth and waist levels in the centerline (Positions 1 and 2); at chest and waist levels toward the prosthetic side (Positions 4 and 5); somewhat less effective toward the sound side (Position 6); and poorest at mid-thigh level in the centerline (Position 3). Above-elbow subjects were most proficient at two waist-level positions (Positions 2 and 5); somewhat less effective at waist level on the sound side (Position 6), at chest level toward the prosthetic side (Position 4), and at mid-thigh in the centerline (Position 3); and poorest at mouth level in the mid-line (Position 1), all of which suggests that the most efficient use of the above-elbow prosthesis is to be had at 90 deg. of forearm flexion and that less efficient operation occurs when the forearm is flexed appreciably more or appreciably less than 90 deg. Shoulder-disarticulation subjects were most proficient in handling objects at waist level, either in the mid-line or toward the prosthetic side (Positions 2 and 5).

Table 28

MEAN PERFORMANCE RATINGS AND STANDARD DEVIATIONS IN POSITIONING TESTS

Position	Evaluation I				Evaluation II			
	Below-Elbow (N = 71)		Above-Elbow (N = 49)		Below-Elbow (N = 71)		Above-Elbow (N = 49)	
	MPR	σ	MPR	σ	MPR	σ	MPR	σ
1	6.9	1.3	4.1	2.4	7.2	1.3	4.9	1.6
2	7.1	1.4	5.2	1.7	7.3	1.2	5.9	1.5
3	6.0	1.4	4.3	1.8	6.3	1.4	5.1	1.7
4	6.7	1.3	4.6	1.9	7.1	1.4	5.1	1.7
5	6.8	1.2	4.9	1.6	6.9	1.3	5.8	1.6
6	6.3	1.6	4.5	1.7	6.8	1.3	5.3	1.8

Among both above- and below-elbow patients, skill in operating the terminal device in different positions improved significantly after treatment, a result more positive than that obtained from the corresponding prehension test, where improvement was statistically significant for above-elbow amputees only. Analysis of the pre- and post-treatment ratings of the below-elbow amputees revealed significant improvements (Table 29) in the ability to operate their terminal devices in three positions—at waist level in the mid-line (Position 2), at chest

Table 29

SIGNIFICANCE OF DIFFERENCE (P)[a] BETWEEN RATINGS OF ABSTRACT PERFORMANCE

Test	Significance of Difference (P)[a] Between Below-Elbow Cases and Above-Elbow Cases in Abstract-Performance Ratings		Significance of Difference (P)[a] Between Abstract-Performance Ratings at Evaluation I and at Evaluation II	
	Evaluation I	Evaluation II	Below-Elbow	Above-Elbow
Prehension	<0.01	<0.01	0.14	<0.01
Positioning				
1	<0.01	<0.01	0.06	0.03
2	<0.01	<0.01	0.16	0.02
3	<0.01	<0.01	0.12	<0.01
4	<0.01	<0.01	0.05	0.07
5	<0.01	<0.01	0.42	<0.01
6	<0.01	<0.01	0.02	0.01

[a] The letter P represents the probability that the difference obtained between the mean of each test occurred by chance. Any P value exceeding 5 chances in 100 (0.05 level) can be taken as indicating no substantial difference between the tests.

level toward the prosthetic side (Position 4), and at waist level toward the sound side (Position 6).

The time required by the amputees to complete each of the six tests did not appear to be related to the particular position involved, nor did performance time seem to be affected by the treatment process (Table 30). For the below-elbow cases, mean performance times for all six tests varied between 5 and 7 sec. in both pre- and post-treatment evaluations. Similarly, the above-elbow cases performed each of the six tests in approximately the same average time (10 to 16 sec. at Evaluation I, 9 to 14 sec. at Evaluation II).

Although by definition the positioning test is "abstract," the level of performance in the several positions bears a relationship to the ability that may be expected in the performance of practical activities in the same positions. Improved performance in the test should be reflected either in greater ease in use of the prosthesis or else in the ability to perform more activities with it. Since in all cases there was an improvement in test performance after treatment, there is strong indication that treatment resulted in improved skill in utilizing a prosthesis in the positions required for the pursuit of the normal pattern of daily activities. While the available evidence is not wholly definitive, the distinct shift toward higher scores after treatment must be taken as indicating a general improvement in achievement level.

Table 30

MEAN PERFORMANCE TIMES AND STANDARD DEVIATIONS IN POSITIONING TESTS

Position	Evaluation I				Evaluation II			
	Below-Elbow (N = 68)		Above-Elbow (N = 40)		Below-Elbow (N = 68)		Above-Elbow (N = 40)	
	MPT (sec.)	σ	MPT (sec.)	σ	MPT (sec.)	σ	MPT (sec.)	σ
1	5.9	4.3	12.0	8.5	5.2	2.5	13.6	11.3
2	6.0	3.7	10.3	6.5	5.4	3.2	11.0	7.8
3	6.1	4.4	11.2	10.8	5.6	2.9	9.9	4.8
4	5.8	2.9	16.1	17.5	5.9	4.4	11.0	7.1
5	5.7	3.7	10.7	6.4	6.0	4.8	9.1	4.3
6	6.5	8.1	11.1	8.7	5.3	2.9	11.0	6.6

PRACTICAL-ACTIVITIES TESTS

In contrast to the abstract tests of prehension and of positioning a prosthesis, the practical-activities tests were designed to evaluate the amputees' ability to integrate the mechanical operations of prehension and positioning into the efficient performance of a complete and meaningful task. From the list of 20 tasks there were selected for each amputee eight specific test activities which, according to the subject's own statements, occurred most frequently for him in his normal activity pattern and to which he himself attributed the most importance. By virtue of these criteria some tasks were tested less frequently than others. The present analysis involves only those activities performed by 10 or more subjects.

On this basis, the below-elbow subjects received substantially higher scores than did the above-elbow cases, a fact which only substantiates the superior ability of the below-elbow

amputee in coping with daily needs. The average, weighted, pretreatment performance rating was 6.4 in below-elbow cases, 5.0 in above-elbow cases. After the treatment program, the corresponding figures were 7.0 for the below-elbow and 6.2 for the above-elbow patients (Tables 31 and 32). The scores of the few shoulder-disarticulation cases tested were far below those of either below-elbow or above-elbow amputees.

If we consider that a score of 10 represents normal nonamputee performance, then the average score of 7.0 obtained by the below-elbow population for all 20 activities represents a creditable performance. For some tasks, of course, the average was higher than 7.0, and certain individual amputees consistently outperformed the average. It may thus be concluded that below-elbow subjects generally perform common daily tasks in a smooth, relatively unobtrusive, errorless manner. Although they never attain a level of skill equal to that of the nonamputee, they (and particularly the better performers in the group) tend to approach that level of performance.

The post-treatment skill of the above-elbow group, represented by an over-all weighted-average rating of 6.2, indicates a relatively high level of performance. While the need for an elbow-lock control motion, together with the greater body distortion that results from the lack of an anatomical elbow, reduces the functional level of the above-elbow amputee to less than that of the below-elbow group, the above-elbow patient is nevertheless capable of more or less skillful use of a prosthesis.

Table 31

PRACTICAL-ACTIVITIES TESTS

PERFORMANCE RATINGS AND TIME IN BELOW-ELBOW SUBJECTS

Activity	No. of Cases	Evaluation I				Evaluation II				Difference Between Mean Ratings[a] (Evaluation II vs. Evaluation I)	Difference Between Mean Times[a] (Evaluation II vs. Evaluation I)
		Mean Rating	σ	Mean Time (sec.)	σ	Mean Rating	σ	Mean Time (sec.)	σ		
Assist someone with coat	12	7.1	0.9	8.4	3.4	7.2	1.9	9.8	7.6	+0.1	+1.4
Button shirt sleeve	37	6.6	1.4	6.6	4.4	6.9	1.9	6.7	4.1	+0.3	+0.1
Carry cafeteria tray	6	7.3	—	11.6	—	7.5	—	9.6	—	—	—
Carry several packages	32	7.3	1.2	13.5	6.7	7.4	1.4	14.3	6.1	+0.1	+0.8
Cut food with knife and fork	27	6.4	1.4	21.6	11.4	7.0	1.3	24.6	20.7	+0.6	+3.0
File fingernails	29	5.9	1.5	19.6	11.6	7.1	1.4	19.2	8.7	+1.2	−0.4
Hammer a nail	15	6.2	1.4	11.0	2.4	7.2	1.4	12.1	6.3	+1.0	+1.1
Hold telephone	9	5.9	—	27.0	—	6.6	—	22.3	—	—	—
Open jar	40	5.8	1.8	7.6	3.8	7.0	1.5	7.8	3.6	+1.2	+0.2
Play cards	2	7.5	—	14.0	—	6.0	—	25.0	—	—	—
Put on glove	12	6.3	2.4	17.2	15.7	7.4	1.6	10.3	18.3	+1.1	−6.9
Take bills from wallet	60	6.3	1.5	11.3	4.4	6.7	1.4	11.5	4.3	+0.4	+0.2
Tie necktie	22	6.0	1.8	34.7	23.2	6.5	1.9	30.5	12.5	+0.5	−4.2
Tie shoelaces	37	7.0	1.7	17.8	8.9	7.5	1.2	17.7	5.7	+0.5	−0.1
Use brush and dustpan	13	6.0	1.0	17.4	7.2	7.5	1.6	14.6	6.9	+1.5	−2.8
Use can opener	22	6.0	2.0	10.4	2.0	6.5	1.8	9.7	4.3	+0.5	−0.7
Use "Flit" gun	2	7.5	—	17.5	—	7.5	—	16.0	—	—	—
Use paper clip	43	6.4	1.9	12.6	7.0	6.9	1.3	11.4	3.5	+0.5	−1.2
Use pencil sharpener	32	6.7	2.8	14.0	9.2	7.1	1.9	13.4	7.4	+0.4	−0.6
Wire electric plug	1	9.0	—	82.0	—	6.0	—	115.0	—	—	—
Over-all mean rating		6.4				7.0					

[a] For activities performed by 10 or more subjects only.

Table 32

PRACTICAL-ACTIVITIES TESTS

PERFORMANCE RATINGS AND TIME IN ABOVE-ELBOW SUBJECTS

Activity	No. of Cases	Evaluation I				Evaluation II				Difference Between Mean Ratings[a] (Evaluation II vs. Evaluation I)	Difference Between Mean Times[a] (Evaluation II vs. Evaluation I)
		Mean Rating	σ	Mean Time (sec.)	σ	Mean Rating	σ	Mean Time (sec.)	σ		
Assist someone with coat	3	5.3	—	11.0	—	7.7	—	10.0	—	—	—
Button shirt sleeve	4	4.8	—	16.3	—	6.8	—	8.4	—	—	—
Carry cafeteria tray	3	3.7	—	19.3	—	6.5	—	14.7	—	—	—
Carry several packages	30	5.3	1.8	18.1	9.6	6.3	1.3	17.5	8.1	+1.0	−0.6
Cut food with knife and fork	6	4.2	—	37.3	—	6.5	—	29.3	—	—	—
File fingernails	20	5.1	1.4	29.8	19.6	6.1	1.1	21.4	10.7	+1.0	−8.4
Hammer a nail	11	5.0	1.0	13.0	5.5	6.6	1.4	15.3	5.5	+1.6	+2.3
Hold telephone	2	3.0	—	45.0	—	8.0	—	24.5	—	—	—
Open jar	18	4.6	1.9	16.1	14.2	6.5	1.3	10.8	7.5	+1.9	−5.3
Play cards	8	4.6	—	17.7	—	6.4	—	15.9	—	—	—
Put on glove	10	4.6	2.6	20.7	11.4	5.6	2.0	15.6	8.5	+1.0	−5.1
Take bills from wallet	23	4.9	1.8	14.3	7.8	5.7	1.6	15.4	7.7	+0.8	+1.1
Tie necktie	10	4.8	1.8	39.6	8.4	5.6	0.8	33.6	9.4	+0.8	−6.0
Tie shoelaces	14	5.7	1.3	23.6	13.4	6.4	1.2	18.4	9.7	+0.7	−5.2
Use brush and dustpan	4	3.5	—	27.0	—	5.3	—	17.8	—	—	—
Use can opener	13	5.0	1.8	14.1	8.7	6.8	1.4	11.1	6.8	+1.8	−3.0
Use "Flit" gun	1	2.0	—	20.0	—	6.0	—	18.0	—	—	—
Use paper clip	22	5.2	1.7	15.6	6.4	6.5	1.4	13.1	5.0	+1.3	−2.5
Use pencil sharpener	15	4.5	1.4	19.9	12.5	5.9	1.5	15.9	12.5	+1.4	−4.0
Wire electric plug	3	4.3	—	167.3	—	5.3	—	105.0	—	—	—
Over-all mean rating		5.0				6.2					

[a] For activities performed by 10 or more subjects only.

In the post-treatment evaluation, the below-elbow subjects generally performed better in all of the 15 activities studied. Increases in the ratings ranged from a low of 0.1 point to a relatively significant 1.5 points. Although the average increase (0.6 point) was not substantial, all of the changes were in the expected direction, an increase of a full point or more being achieved in five of the activities. A similar trend characterized the performance of the above-elbow subjects, where improvement (ranging from 0.1 point to 2.8 points) occurred in all 11 activities studied. In eight of the activities there was a gain of at least one full point, the average for all 11 being 1.2 points. The magnitude of the gains and the number of activities in which significant improvement occurred were both greater than in the case of the below-elbow subjects.

It should be noted that most of the 20 shoulder-disarticulation amputees taking the test at the post-treatment evaluation were capable of performing six to eight of the 20 activities. Apart from considerations of the quality of performance, this outcome represents a significant increase in the number of activities those subjects were capable of performing.

DISCUSSION

Proficiency in the use of arm prostheses is clearly related to level of amputation. The performance of the below-elbow amputees in the NYU Field Studies was found to be consistently better and faster than that of the above-

elbow amputees, who in turn performed better and faster than did the few shoulder-disarticulation amputees involved. Differentiation of performance was apparent in all tests, both before and after treatment.

The most important single reason for the superior performance of the below-elbow amputee lies in his retention of the natural elbow. The above-elbow amputee is required to operate a mechanical elbow scarcely designed to provide *all* the functions of the natural elbow. Coupled with this mechanical limitation is the relatively high degree of skill required to operate present-day mechanical elbows smoothly and unobtrusively. Together these two factors impose upon the level of above-elbow prosthetic performance an insurmountable upper limit. The difficulty is only magnified in the case of the shoulder-disarticulation amputee, who must operate both a terminal device and a mechanical elbow by scapular abduction, a motion more gross and yet more limited than the humeral flexion normally available to both above- and below-elbow amputees. Further development and refinement of existing elbows and an increased emphasis on amputee training could conceivably elevate the level of above-elbow and shoulder-disarticulation performance to some degree. But radical changes to bring the above-elbow or shoulder-disarticulation amputee functionally up to par with the below-elbow case must await new concepts and designs in the development of components and control systems.

As a result of the treatment program in the NYU Field Studies, the ability of all the amputee subjects to use their prostheses improved to varying extent. The superiority of the newer components and newer fabrication procedures, and the systematic training given to each patient as a routine matter, contrived to produce a general benefit differing only in degree from subject to subject and from amputation level to amputation level. That the improvement in performance among the below-elbow amputees was relatively small indicates that as a group they derived the least benefit from the new developments, for the obvious reason that their relatively high level of proficiency prior to the studies discounted their ability to profit greatly from the program. The more significant gains made by the above-elbow and shoulder-disarticulation amputees identified these groups as the major beneficiaries of the Field Studies. Although as a group the above-elbow subjects never quite attained the achievement level of the below-elbow amputees, the gap between them was significantly smaller after the treatment program, and as individuals the few shoulder-disarticulation cases improved markedly.

The prostheses prescribed in the program were designed to provide maximum comfort, freedom of movement, and optimal replacement of lost function. The more significant improvements included higher, better-fitting, and better-appearing sockets; more useful and more easily operating elbows; improved efficiency of force transmission through better cable alignment and use of more stable materials; lighter, freer, and more comfortable harnessing; and a marked increase in the use of terminal devices offering improved control of grasp force. The advantages offered by these features were apparent in the prehension test, in which the objects to be manipulated remained stationary and the amputee was required to place himself and his terminal device in the best position for grasp and release. The need for compensatory body movements, which tend to lower performance ratings, was clearly reduced by the increased freedom and mobility of the new arms. The increased control of finger pressure offered by the new devices was reflected in the general and significant decrease in the number of compression errors made at the second evaluation.

The value of the newer elbows seemed to be demonstrated by the improvement in performance of the above-elbow cases in the positioning test. The higher scores on the second test were based on more accurate positioning of the terminal device with lessened body contortion—a function of the elbow unit. It is interesting to note that, while performance ratings improved after treatment, speed of performance remained static. With the wider use of APRL devices on the second evaluation, an *increase* in the time required might have been expected. Since operating time did not increase, improved control of finger pressure was achieved without a concomitant slowing of performance.

The similarity in performance patterns in the abstract-function and practical-activities tests may have important clinical consequences. Further study is warranted to see whether proficiency in the practical utilization of a prosthesis is related to, and perhaps reflected by, performance in abstract-function tests. Should such a relationship be found, it would be possible to convert the easily administered abstract-function test from a research tool to a clinical instrument. A combination of the more sensitive and selective elements of the tests could provide the foundation for a reliable system of measuring achievement and proficiency in amputee training.

As a result of the Upper-Extremity Field Studies, it is now possible to establish a set of proficiency norms based upon amputee performance but retaining as its main criterion the skill patterns of nonamputees. The therapist who trains an arm amputee to use a prosthesis could thus have available a realistic and relatively objective standard against which to evaluate the progress and achievement of each patient, since she would be comparing his performance with that of hundreds of amputees of a similar type. The resulting improvement in the evaluation of training effectiveness should permit a judicious allocation of training time and services. Despite its inadequacies of crudeness and of administrative difficulty, the performance-evaluation system described here established for the first time a logical plan for ascertaining the degree of functional restoration offered amputees by modern prosthetics services, a problem heretofore frequently bypassed for lack of reliable and valid methods.

Concluding Remarks

Refinement of the existing research tools on the basis of past experience, reapplication of these methods in the light of present knowledge, and the further correlation of results may well make it possible to predict the anticipated outcome when specific prosthetic components are applied to a particular arm amputee. Such an eventuality may lead to major changes in the principles of arm prescription and fitting as currently embodied in the art-science of upper-extremity prosthetics.

The results of these studies, which have been analyzed and interpreted in the discussion sections on pages 54–61, 99–103, and 143–149, are not resummarized here by way of concluding this article. It is perhaps sufficient to close with the remark that there has been presented in this article a large volume of information providing new insights—some clear, some tentative—into the over-all problem of evaluating arm prostheses. The surface of this broad field has been partially mapped along with some scattered probings of the substrate; but certainly the way has been opened for those who may elect to pursue this problem a little further.

Appendix I
Reliability and Validity of the Test Methods

Reliability

It is well known that test results are subject to a variety of influences and that therefore errors of measurement are to be expected under the best of experimental conditions. The tests used in the NYU Field Studies were at the time in a developmental stage, and in anticipation of errors tending to reduce reliability several precautionary steps were taken.

Three measures were employed in scoring the performance tests—performance rating, number of errors, and time. The reliability of the last two is not open to serious question, since such errors as are likely to occur in counting errors or in reading a stopwatch are not usually of significant magnitude or of a systematic nature and can be expected to vary randomly and "average themselves out." Performance ratings, being based on judgment, are more variable, so that errors tending to reduce reliability are to be expected. Some of the principal sources of bias in this study may have been:

1. *Errors of Leniency.* Judges tend to rate higher in the desirable traits the subject they actually know.
2. *Errors of Central Tendency.* Judges hesitate to give extreme ratings and so tend to displace subjects in the direction of the average for the entire group, thus misrepresenting the true variation in the group.
3. *Halo Effect.* We tend to judge in terms of the general mental attitude toward the test situation. Knowing, for example, that a subject is being tested for the second time, with an intervening period of fitting and training, a judge may tend to upgrade the performance unduly.
4. *Normal Variation in the Attitude of the Judge.* As individuals, we are continuously influenced by our physical environment and emotional status, and the net effect may produce variability in judgment.
5. *Variations in Judges' Values.* A judge's preconception about the relative difficulty of activities, or of the value to be placed upon efforts in relation to achievement, may bias his judgment.

During the course of the studies, 12 NYU Field Representatives conducted the performance tests over a 3-year period between 1953 and 1956. At no one time were all of the judges active in the work, and as a result they did not conduct equal numbers of tests. Nor was it always possible for the pre- and post-treatment evaluation of a patient to be judged by the same rater. Steps were therefore taken to maintain the reliability of the ratings by familiarizing judges with probable sources of error and by firmly establishing the judgment criteria. In addition, all judges were highly qualified members of the NYU staff, with previous research experience in testing and assessment. All were either graduates of the course in upper-extremity prosthetics at UCLA or else had been given similar instruction at New York University. Moreover, the criteria for evaluating performance were carefully studied in formal sessions by all the judges to aid in the development of consistent standards of judgment. The effectiveness of these steps in maintaining reasonable reliability was gauged by statistical analysis.

Evidence of reliability was obtained by comparing periodically the independent but simultaneous ratings of a single performance as arrived at by several judges. The ratings thus obtained were evaluated by means of a statistical procedure involving Kendall's Coefficient of Concordance,[1] which indicates the degree to which a number of raters are applying essentially the same standard. Kendall's coefficient (W) is used to evaluate the difference between the variability in a set of ratings actually obtained and the variability to be expected in a hypothetical set of ratings *if there were perfect agreement among all the raters.* The resulting single measure of the extent of agreement among several judges is usually expressed as a chi-square function [$\chi^2 = p(m-1)\,W$, where m = number of judges and p = number of scores]. If the difference (in degree of variability) between the obtained and the hypothetical sets of ratings is significant (by statistical test), we may assume that not all of the raters were applying the same judgmental standard. Since of the original 12 raters in the Field Studies only eight rated enough cases for the results to

[1] Siegel, S., *Nonparametric Statistics for the Behavioral Sciences*, McGraw-Hill, New York, 1956.

be valid, only these eight were included in this and succeeding analyses of homogeneity. The statistical findings ($\chi^2 = 14.47$; $df = 7$; $P < 0.05$) indicated that a hypothesis of no relationship between the sets of ratings given by each rater is untenable. This may, therefore, be considered as indicative of a satisfactory degree of consistency in the judgments of the raters *at those times*. To test the reliability of the scores given by the judges during the *entire test period*, another technique, "analysis of variance," was used.

"Analysis of variance" is a statistical procedure by which a number of independent samples or sets of scores may be tested simultaneously to determine whether or not they are sufficiently similar to be pooled. It is an efficient method for evaluating inter-rater reliability when more than two raters are involved. The test is expressed in terms of a ratio, F, which describes the relationship between the variability of the scores among the several raters (between groups) and the variability of each rater's scores from the mean of all raters (within groups). Simply stated, it is a test of a hypothesis that the scores given by any one rater did not vary significantly from the average of the scores given by all the raters. As shown in the relationship

$$F = \frac{\text{variability between groups}}{\text{variability within groups}},$$

the larger the variance from one rater to another (between groups) as compared with a single rater's variance from the common mean (within groups), the larger the fraction (F). A large F signifies a great difference between the raters; an F of low value indicates homogeneity in the group. A low ratio therefore indicates that performances were consistently rated, that the raters are therefore interchangeable, and accordingly that all the ratings may be considered as having been given by the same rater.

Because of the small number of cases involved, this technique could not be applied to the data from the practical-activities tests or from the abstract-function tests for the above-elbow sample at the pretreatment evaluation. It was applied to the ratings given the below-elbow cases on administration of both the prehension and the positioning test and to the ratings given the above-elbow cases at the post-treatment evaluations (Table 1). There were thus 21 tests in which individual raters had scored enough cases for reliability studies to be made by this means. Used were only those ratings given to subjects evaluated on both pre- and post-treatment tests by the same group of raters. Which is to say that, although an individual rater may not have scored the same subject on both evaluations, he was a member of a group of raters who had given all the ratings.

Of the 21 tests, 17 were not significantly different (0.05 level). That is, the extent to which they varied is well within the relatively narrow limits of chance fluctuation, which indicates an acceptable degree of consistency and reliability among the raters. Four, footnoted in Table 1, were statistically significant beyond the 0.05 level of confidence (*i.e.*, there was enough variation in the ratings in these tests to raise a question about the consistency of rating standards).

Despite the significant F value obtained in the four questionable tests, all results were used in this report. While the lower statistical reliability of the four may indicate rater unreliability or instability due to smallness of the sample (which would suggest the possibility of eliminating either these tests or the extreme raters), they were retained because the results clearly followed the trend of those tests appearing more reliable statistically. Since, furthermore, all of the tests are, or were, in a developmental stage, no theoretical reason could be adduced for their low reliability. There seemed to be greater value in retaining all of the tests and analyzing the conditions affecting reliability than in discarding some tests on statistical grounds alone. Considering the implications of the findings from all 21 tests, the ratings seemed homogeneous enough to warrant pooling.

Validity

To establish the validity of a test on empirical rather than logical grounds requires a previously established independent criterion with which to compare the test in question. The degree of correspondence between the two (*i.e.*, the extent to which the test measures the same variable as does the independent criterion) is

Table 1
MEASURES OF INTER-RATER RELIABILITY

Test	Evaluation I					Evaluation II							
	Below-Elbow				Above-Elbow	Below-Elbow				Above-Elbow			
	F	df	F Significant[a] 0.05 level	F Significant[a] 0.01 level		F	df	F Significant[a] 0.05 level	F Significant[a] 0.01 level	F	df	F Significant[a] 0.05 level	F Significant[a] 0.01 level
Prehension	1.96	4,48	2.56	3.74	Not Tested	2.32	3,35	2.78	4.16	2.21	3,36	2.86	4.38
Positioning 1	2.23	4,44	2.58	3.78	(Insufficient	1.72	4,60	2.52	3.65	2.34	3,34	2.88	4.42
Positioning 2	1.03	40,4	5.71	13.74	Number of	3.23	50,4	5.70	13.69	1.32	3,34	2.88	4.42
Positioning 3	1.65	4,44	2.58	3.78	Subjects)	1.08	4,60	2.52	3.65	1.24	3,34	2.88	4.42
Positioning 4	1.91	4,44	2.58	3.78		3.54[b]	4,60	2.52	3.65	3.97[b]	3,34	2.88	4.42
Positioning 5	1.58	4,44	2.58	3.78		5.27	50,4	5.70	13.69	7.51[b]	3,34	2.88	4.42
Positioning 6	1.38	30,3	8.62	26.50		1.52	4,55	2.54	3.68	10.06[b]	3,34	2.88	4.42

[a] The threshold value of F at which differences can be considered significant for a given number of raters and subjects.

[b] Unreliable. That is, it cannot be said, with an acceptable degree of confidence, that differences in this rating are due to chance rather than to bias on the part of the raters.

the extent of test validity. External criteria usually are: a specific outcome or product of an activity (as, for example, the number of words typed by a typist in a specific time is a criterion of typing speed), or the activity itself (as illustrated by the speed of a runner as a criterion of fleetness of foot), or the judgment of persons qualified in a given field. The abstract-function tests—the prehension test and the positioning test—require activities which correspond closely to the skills being measured (*i.e.*, to the ability to grasp a very wide variety of objects and to operate a terminal device in several useful planes). No other criteria appear more germane. The practical-activities tests derive their validity in the same fashion—each activity is a valid test since it is itself the skill being measured.

To go a step further and to determine whether all or none of these tests are also useful measures of "prosthetic utilization" or of "extent of functional restoration" or of "rehabilitation" requires broader study and the use of other criteria. The presently available judgment of qualified clinic personnel may be the most useful criterion with which the tests may be compared. If, for example, the way in which amputees were classified on the basis of the test results was closely related to qualified judgment about amputee achievement, it would tend to establish the validity of the test as a measure of prosthetic utilization. Such an analysis is beyond the scope of the present work but remains as an interesting avenue for further study.

Studies of the Upper-Extremity Amputee

VII. Psychological Factors

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With the possible exception of the introductory Section I (Artificial Limbs, Spring 1958; Vol. 5, No. 1), the foregoing presentations in this series have in general been concerned with the biomechanical aspects of the man-machine entity in prosthetic restoration. If, however, our understanding of amputee needs and limitations is to be comprehensive, we must inquire also into the mental and emotional characteristics of the man served by the machine. Consideration of the psychological factors in amputee rehabilitation was therefore an important aspect of the Upper-Extremity Field Studies, and the results of these investigations are summarized in this three-part article. The first part, *Personality Dynamics of Amputees,* discusses a number of the psychological variables that are relevant to amputation. The second deals with *Social and Functional Factors in Prosthetic Wear.* And the final one, *Attitudes Toward Prosthetic Wear, Before and After Fitting,* describes the attitudes shown toward arm prostheses by amputees who had never before worn an artificial arm. The rationale of the study, and the data-collecting instruments here referred to as "appendices," are all to be found in Section I (Artificial Limbs, Spring 1958; Vol. 5, No. 1; pp. 46 through 56).

Personality Dynamics of Amputees

At present no single theory, or combination of theories, encompasses all the central problems arising in man from the loss of a limb. One reason for this circumstance is that the special problems and needs of the amputee have never been defined adequately. What does an amputation mean to the amputee? What does it mean to his family, friends, and co-workers? What reaction does the amputee have to his loss? How is he affected socially, vocationally, emotionally? Does his amputation cause basic psychological changes? What major needs are frustrated? What new needs arise? Does prosthetic restoration affect personality restoration? These are but some of the questions that seem pertinent and to which answers were sought during the NYU Upper-Extremity Field Studies.

A probing of specific amputee problems was considered to be the most fruitful approach, and accordingly a set of questions was designed to elicit information about areas in which the amputee might be expected to have significant problems. By means of a 57-item, multiple-choice questionnaire (Appendix IIIE), supplemented by a 9-item instrument calling for narrative answers (Appendix IIIF), nine personality variables (acceptance of loss, identification with the disabled, functional ade-

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quacy, independence, sensitivity, appraisal of acceptance by others, sociability, frustration, and optimism) were identified and defined. Of 359 adult male amputees who responded in this phase of the investigation, all but 55 were currently wearing prostheses or had worn one in the past.

Each of the nine personality variables has many ramifications, and it was possible to investigate a limited number only. Moreover, a preliminary analysis indicated that the data did not differ significantly for different levels of amputation, and accordingly the responses of the three groups (below-elbow, above-elbow, and shoulder-disarticulation) were combined. The results therefore represent only an early exploration of the field with two principal purposes—first, to stimulate further inquiry, and, second, to build a more general awareness of the psychological aspects of treating and dealing with amputees. While the central concept of each variable is discussed here, emphasis has been placed on principles of theoretical and practical interest to those concerned with the management of amputees. Whenever possible, the interrelationships between a particular concept and other variables are examined, and an effort is made to bring out implications for research and practice. Vocational attitudes provided an additional area of interest, as did also the shifts in the valuation of prosthetic service.

The data presented are chiefly those gathered after the period of treatment and fitting. Although the treatment procedure produced few measurable changes of any consequence, where such changes were observed they are also discussed.

ACCEPTANCE OF LOSS

"Acceptance of loss" refers to the amputee's ability to accept the physical limitations that result from his injury, to avoid depreciating or pitying himself, and to recognize the social implications of his loss without exaggerating or denying them. This matter was explored by means of questions relating to the amputee's adaptation to his loss, his wishful thinking about the lost limb, and his reaction to the artificial one.

When the treatment period was over, most of the subjects claimed to be adapted to their loss:

TO WHAT EXTENT DO YOU FEEL THAT YOU HAVE BECOME ADAPTED TO THE LOSS OF YOUR LIMB?

Completely	42%
Almost completely	32
Considerably	16
Somewhat	5
Slightly	5

Before the treatment period, only 35 percent of the amputees said that they felt completely adapted to their loss. The increase to 42 percent after completion of the treatment program would seem to indicate that the fitting of the artificial limb had a strong positive effect upon the adaptation of at least a small number of amputees.

Although 90 percent of the amputees claimed either complete, almost complete, or considerable adaptation to their respective losses, it is doubtful that so many had really achieved it. While some may truly have accepted their physical loss and its implications, there were surely many who were trying to maintain feelings of bodily integrity and adequacy by denying the personal and social concomitants of amputation. Clearly, they preferred to de-emphasize regret and any hint of abnormality and difference. In keeping with this feeling, 86 percent of the amputees said that they rarely, very rarely, or never felt sorry about their loss:

DO YOU FEEL SORRY THAT YOU'RE AN AMPUTEE?

Most of the time	1%
Sometimes	13
Rarely	12
Very rarely	33
Never	41

But it should be noted that many amputees *do* admit that they have fantasies about the matter:

DO YOU FIND YOURSELF WISHING YOU WERE A TWO-HANDED PERSON?

Much of the time	8%
Sometimes	45
Rarely	9
Very rarely	28
Never	10

A second question also explored this phenomenon:

DO YOU EVER THINK OF HOW MUCH BETTER OFF YOU WOULD BE IF YOU HAD NOT LOST AN ARM?

Frequently	6%
Sometimes	32
Rarely	16
Very rarely	32
Never	14

Thus it appears that, although most amputees try to avoid thinking about themselves as amputees, regrets over their loss *do* come out in fantasy. Other indications of this subconscious process can be seen in the contradictory data resulting from different avenues of questioning. About half of the amputees indicated that they frequently tried to perform with their prostheses tasks which they knew would be difficult, and approximately the same number said that what bothered them most was "the inability to perform as I used to." Both of these reactions, which persisted throughout the entire period of participation in the program, seem to represent the amputee's attempt to retain his status as an active, competent, and self-sufficient person. But an amputee who frequently tries to use his artificial arm for a task that he knows will be difficult must have an unrealistic attitude toward his physical limitation. He is evidently demonstrating an unwillingness to accept the full implications of his loss.

Among the many considerations involved in the loss of an arm, the most obvious is the inability to perform at one's previous level. Others are the loss of normal appearance and the thought of not being like other people. Although 57 percent of the amputees said that performance was their most bothersome problem, while only 15 percent mentioned the other two considerations, it is difficult to accept such a response at face value. It is likely that the loss of normal appearance and the thought of not being like other people bother amputees far more than they are willing to admit.

Two factors lead us to this belief. First, we are convinced that people (and men in particular) hesitate to admit that they are concerned over their appearance or over the thought of not being like other people. An amputee probably finds it much more acceptable, both personally and socially, to seize upon the very real functional and vocational problems caused by his amputation and to use them as the "real" causes of his distress. Secondly, an amputee who admits to being bothered by his inability to perform is really also saying that he is concerned about being different from others, since performance difficulties as well as altered appearance make one "different."

Amputation has also other, less obvious aspects that are even more difficult for the amputee to accept. These involve the subconscious effects of the loss, such as the thwarting of life goals, threats to masculinity-femininity identifications, and the arousal of latent fears of castration. Although the reality and importance of these problems have repeatedly been demonstrated clinically, controlled investigation designed to explore them is exceptionally difficult and has not yet been undertaken. Hence most of the subconscious effects of amputation cannot yet be evaluated systematically, even though it seems clear that they exert a great influence upon the amputee's acceptance or nonacceptance of his loss.

In general, it may be concluded that an amputee's acceptance of loss depends upon many factors, the most important usually being beyond his own control. His ability to accept depends upon his conscious and subconscious interpretation of his status. If he feels that his amputation has relegated him to an inferior social and vocational status, that he can no longer achieve his principal goals, that he is inferior, and that he has been reduced in functional and sexual potency, he will naturally attempt to reject the implications of his loss. If he looks upon his amputation as a means of escaping from the competition of everyday life, he may accept his loss. If it justifies catering to his need to feel dependent, he may even derive satisfaction from it. But when the amputee is able to look upon his experience as primarily a major frustration that must be overcome—and that *can* be overcome by his own efforts, in cooperation with family, friends, and rehabilitation person-

nel—then the stage is set for a real acceptance of loss.

Although it seems clear that when first seen many of the participating amputees had not achieved full acceptance of their loss, experience shows that, after the early postamputation period of readjustment, and after satisfactory prosthetic fitting, most amputees *do* accept their loss to a significant degree.

IDENTIFICATION WITH THE DISABLED

"Identification with the disabled" refers to the degree to which the amputee considers his abilities, general appearance, and personality similar to those of other persons physically impaired. To a great extent this factor serves as the basis for his interaction with others.

The basic question exploring this matter was:

I THINK OF MYSELF AS A:

physically abnormal person.	1%
normal person except for a major physical defect.	18
normal person except for a slight physical defect.	29
normal person except for a very slight physical defect.	24
completely normal person.	28

Obviously the subjects tended to describe themselves as normal persons and to deemphasize their physical defects. Of particular interest are the 28 percent who described themselves as completely normal, not even conceding a "very slight" defect.

Few of the subjects admit that amputation is of considerable consequence:

DO YOU THINK BEING AN AMPUTEE MAKES:

a considerable difference?	7%
some difference?	31
a slight difference?	19
a very slight difference?	26
no difference at all?	17

In keeping with their expressed tendency to place the fact of amputation in the background, and to consider themselves physically normal persons, most claimed that they often forgot about their amputations:

I FORGET THAT I AM AN AMPUTEE:

never.	7%
rarely.	4
sometimes.	21
most of the time.	61
all of the time.	7

Still tending to play down any differences, 67 percent of the subjects said that they thought amputees had about the same number of personal problems as did nonamputees. At the start of the treatment program, only 57 percent of the amputees felt that way. But even then a sizable minority (30 percent) believed that amputees did have more personal problems than nonamputees. In any case, it is noteworthy that, in an area where one might reasonably expect some expression of difference, so large a percentage of the subjects denied any difference at all. A strong tendency to reject any hint of abnormality or "difference" appears throughout the study.

In setting goals and evaluating achievements, most of the amputees would like to be considered as nondisabled persons:

IN DECIDING WHAT YOU SHOULD BE PHYSICALLY ABLE TO DO, DO YOU COMPARE YOURSELF WITH:

very active nonamputees?	16%
active nonamputees?	53
inactive nonamputees?	2
active amputees?	28
inactive amputees?	1

Over two thirds seem to feel that their physical abilities should be comparable to those of active or very active nonamputees. In short, amputees want to be considered normal and would like to discount their physical defects. Since most arm amputees can function in society without serious disadvantage, they would seem to have a sound basis for deemphasizing their handicaps.

There is, of course, a stigma attached to those who are "different," and this circumstance also gives the amputee a strong reason for rejecting identification with the disabled. Thus he tends to maintain that being an amputee does not really "make a difference," although what is certainly implied is that he feels it *should not* make a difference. It is difficult to believe that so many can forget a

fact of such consequence as amputation. But obviously they would *like* to forget it, and many *do* forget it, at least intermittently. For them to repress the amputation completely would be to deny the loss rather than to accept it, and this would be an equally unrealistic type of adjustment. From clinical observation, we have the impression that few amputees wear their loss as a badge, but the fact of amputation does seem to underlie a good part of their behavior. Whether this results in a neurotic fixation or is viewed as one more of life's frustrations to be overcome depends upon the individual.

The fact that 30 percent of the amputees seem to feel that they have more personal problems than do nonamputees should not be taken as showing that amputees are more poorly adjusted than nonamputees. Other studies on physical handicap and amputation have indicated that, although particular problems of adjustment differ, there is generally no marked difference in adjustment between those who are handicapped and those who are not (*1*).

An amputee has mixed conscious and subconscious identifications both with disabled and with nondisabled groups. Whichever group he primarily identifies with provides the basis for his concept of himself, the goals he sets, the aspirations he has, and the way he interacts with others. The amputees in the NYU Field Studies overwhelmingly elected a nonamputee, nondisabled frame of reference. In such a course lie dangers for them—dangers of self-deception, of denial and distortion of reality. Yet advantages follow too. Identifying with the nondisabled provides stimulation and drive to actualize the potential that each amputee has. It helps to combat defeatist attitudes and withdrawal into lethargy and invalidism. The amputee who is able to recognize and accept his identifications with both the disabled and the nondisabled groups maintains the soundest approach to personal adjustment.

FUNCTIONAL ADEQUACY

"Functional adequacy" refers to the amputee's estimate of his level of competence in performing physical activities. Questions were asked exploring the amputee's evaluation of his physical abilities. As has already been seen, over two thirds of the amputees seemed to feel that their physical abilities should be comparable to those of active or very active nonamputees. How well did they think that they met this exacting standard? Generally speaking, they said that they were able to achieve their high goals:

AS COMPARED TO NONAMPUTEES, I AM GENERALLY ABLE TO DO:

much less.	2%
somewhat less.	35
as much.	49
somewhat more.	14
much more.	0

Only about one third conceded that they could not do as much as nonamputees. Furthermore, 68 percent of the amputees said that "very little effort" or "a little extra effort" was required to keep up with nonamputees. Ten percent even claimed that *no* extra effort was required. But 21 percent did admit that "a lot of extra effort" was necessary to keep up with others.

In response to other questions, 92 percent said that they believed their work to be as good as or better than that of their nonamputee co-workers, and 66 percent said they felt they could be employed in jobs requiring "almost as much use of the prosthesis as of the normal hand."

Comparing their present abilities with those had before amputation, 83 percent said they found doing things only "slightly more difficult now." Speaking of the things they could do before their loss, 96 percent said that they could still do "many," "almost all," or "all" of them. Only 8 percent said that being an amputee restricted their capacities "considerably." But 97 percent believed that they could do as much as, or more than, most other amputees.

Here again the optimistic responses show some increase after the treatment period, and there are still other indications that the amputee's feelings of competence are related to the use of the new type of prosthesis. After treatment, 81 percent of the amputees said that they were "very much" or "com-

pletely" satisfied with their prostheses, whereas at the beginning of the treatment program only 58 percent said so. Improved prosthetic equipment and better management procedures seem largely responsible for the favorable results.

Generally speaking, we may describe the picture as follows. The amputee sets high limits to his physical accomplishments, most often aiming to equal the nonamputee. He will sometimes concede that he can do less than a nonamputee, but more often than not he will claim that he can do as much or more. While he almost never admits to a substantial inferiority, he will acknowledge that it takes a little extra effort to keep up with nonamputees. He feels competent to handle the daily routine of living, and he expresses no deprivation associated with his functional limitations. Finally, his estimate of his own abilities increased as a result of participation in the research program.

Taken at face value, this self-picture by the amputee seems a blissful one. But experience indicates that, while some amputees do approach the ideal state, the average patient is far more concerned about his functional adequacy than the responses show. Some of the amputee's description of his high level of competence must certainly be the result of wishful thinking. Concerned with maintaining his self-esteem and confidence, he surely must often distort reality so as to diminish the gap between what he imagines he can do and what he actually can do. And his feelings of great competence may also reflect certain changes in his habits since his amputation—changes that have brought his activities more into line with his new physical abilities.

Complete analysis of functional adequacy requires both objective and subjective estimates of competence and a study of the effect that the difference between the two has upon the amputee's adjustment. In the absence of such an investigation, the data presented are best considered as the responses of people who are concerned with maintaining their self-esteem, their feelings of confidence, and their sense of adequacy. The responses show what the amputee subconsciously desires in the way of treatment from nonamputees. In effect, what we have here is the collective mask that amputees present to the public—and often to themselves. The extent to which we can accept this mask, or how we need to modify it, is a clinical problem that can be resolved only when the amputee's real and fancied achievements are considered in the light of his basic needs.

INDEPENDENCE

"Independence" refers to the extent to which the amputee can make a reasonable effort to be self-sufficient while still feeling free to call for assistance or to use help that is offered. It has been seen that the amputees in this study tend to characterize themselves as self-sufficient. When the amputee knows himself to be capable of handling a situation, he usually declines offers of help:

WHEN I KNOW THAT I AM CAPABLE OF HANDLING A TASK, I:

never accept help.	28%
very rarely accept help.	34
rarely accept help.	12
sometimes accept help.	22
frequently accept help.	4

In keeping with this desire for self-sufficiency, almost three quarters of the amputees said that they rarely or very rarely solicit help:

HOW OFTEN DO YOU CALL FOR HELP FROM OTHERS?

Never	5%
Very rarely	57
Rarely	14
Occasionally	23
Frequently	1

Two facts are of particular interest here. First, the course of treatment provided by the program increased from 49 percent to 57 percent the proportion of those who claimed they very rarely called for help. Secondly, none of the most physically disabled patients (bilateral and shoulder-disarticulation cases) reported frequent calls for help. In answer to other questions, only 1 percent of the amputees said that they refuse help under any circumstances. More than half said that they accept help only when it means the difference between

success or failure. About one quarter said they accept help if it makes the task easier. And 14 percent said they accept help even if it does not make the task easier.

It is clear that the amputee is vitally concerned about his sense of independence. He tends to depict himself as a self-sufficient individual who rejects offers of help whenever he can and who asks for help only occasionally. Despite the stress he places on self-sufficiency, however, the amputee almost always accepts the fact that complete independence is impossible. But he will be practically certain to reject any suggestion of serious dependence.

Why does the amputee value his independence so highly? The answer seems to lie with our society, which places a high premium on personal competence and achievement. The dependent person often finds himself assigned an inferior status in his group. The amputee, constantly faced with this prospect, feels a strong need to prove that he is self-sufficient and that he does not differ from other people. In any case, a handicapped, dependent person is seriously restricted in his ability to reach simple goals that are easily achieved by others (*6*).

Before the amputee can judge the extent of his handicap, he must go through an extensive trial-and-error period, particularly in the early stages of his loss. Depending on how realistically he views his limitations, dependency will or will not become a critical problem. At this point, three kinds of reactions are possible: he may appraise realistically his functional capacities and limitations; he may partly deny his limitations, at the same time often attempting to compensate for them; he may deny his limitations completely.[3] Underlying all three of these reactions is the basic need of all persons to maintain feelings of self-sufficiency—if necessary, by distorting reality. Thus an amputee may distort the extent of his dependence on others and exaggerate his abilities to fulfill society's demands for independence. Conversely, some amputees may distort reality in the other direction, emphasizing their loss in order to help them think of themselves as dependent, affection-seeking persons. In general, however, the amputee's ability to make a realistic appraisal of his capacities, to recognize a certain amount of dependency where it is inevitable, and to ask for help when necessary will depend above all on his feelings of basic security. The amputee who is insecure will be more likely to seek help indiscriminately or to reject it unreasonably (*4,5*).

To avoid overdrawing the negative effects of reality distortion, a distinction must be made between extreme distortion of reality and its temperate shaping. We tend to admit into our perceptions things in line with positive self-feelings and to eliminate or modify those which might cause anxiety. This is a form of adaptive, nonpathological distortion involving control of situations so that, when reality must be faced, it may be done despite the temporary pain associated with the process. Some avoidance of harsh reality is sometimes necessary in order to preserve equanimity in the face of many daily frustrations. In some cases, however, the amputee displays an extreme form of dependence that has been called "invalidism" (*2*). When this happens, the amputee exploits those about him by harping on his incapacities more than his injury warrants. He uses his handicap to avoid responsibilities. While it is true that anyone might be tempted to plead illness to avoid an unpleasant experience, in invalidism the individual employs his loss as a constant way out. Invalidism can also be an attention-getting device as well as an attempt to obtain love that the amputee is not sure of having otherwise. It is used to threaten and control other persons and sometimes provides the disabled person with the means of taking revenge upon others by limiting their freedom of action and making them anxious and guilty.

Whatever the reaction, the family plays an important role in the amputee's attempts to achieve self-sufficiency and yet to fulfill his

[3] The third reaction represents an extremely poor adjustment, for it leads to withdrawal from any situation that might point out the true extent of dependency. Typically, such amputees are characterized by sharply restricted behavior and a limited involvement in life.

needs for dependency. The attitude of the family is often thought to be at least as important as the physical injury itself in determining the amputee's reaction to his disability (*1*). The amputee's attitude toward his family is a combination of a drive for independence and a plea for aid, explicit or implicit. In the ideal family relationship, both needs will be satisfied. But the stress should be upon helping the amputee to take his place in society as a self-respecting, adequate person.

SENSITIVITY

"Sensitivity" refers to the amputee's subjective appraisal of the effect of his physical condition on others and to the feelings of self-consciousness he experiences as a result of this appraisal. Sensitivity about disability may therefore be related to two sources: perception of the negative appraisals of others, and the individual's own self-rejection. These two factors are of course not entirely independent, since an amputee's notions of what others think of him may largely determine what he thinks of himself.

The majority of the amputees in the study readily admitted concern about the opinion of others, but it is noteworthy that almost a fourth of the group refused to admit anything more than a "little" sensitivity:

HOW MUCH DO YOU CARE ABOUT WHAT OTHERS THINK OF YOU?	
Considerably	53%
Somewhat	23
Little	8
Very little	9
Not at all	7

The clinical treatment program had the effect of reducing the self-consciousness admitted. Amputees who said that they never, rarely, or only sometimes felt self-conscious about their personal appearance went from 59 percent before treatment to 72 percent afterward. But 28 percent still said they felt self-conscious most of the time or almost always.

Twenty-one percent of the amputees said that they felt they looked "the same as most people," and 62 percent answered "almost the same as most people." In keeping with this attitude, most of the amputees claimed that they did not feel themselves to be conspicuous. But a significant 22 percent confessed that the idea occurred to them with some frequency:

THE IDEA THAT PEOPLE ARE LOOKING AT ME:	
is almost always on my mind.	2%
sometimes occurs to me.	20
rarely occurs to me.	17
very rarely occurs to me.	38
never occurs to me.	23

The majority of the amputees said that they expected other people to discuss the disability. Only a few believed this occurred frequently, and even fewer denied its existence:

DO YOU THINK THAT PEOPLE TALK ABOUT YOUR DISABILITY?	
Never	3%
Rarely	30
Occasionally	57
Frequently	9
Always	1

Most amputees (67 percent) denied that they felt any resentment over the curiosity of other people. The rest maintained a ratio of three positive reactions (*e.g.*, pride in demonstrating the prosthesis, appreciation of interest) for every negative reaction (*e.g.*, self-consciousness, resentment, nervousness). In all, reactions of annoyance caused by people's curiosity decreased significantly by the end of the treatment period.

Although 99 percent of the amputees said that they seldom or never tried to hide the fact of their amputation, the overwhelming majority said they would not tell a new acquaintance about it unless asked.

The question of whether to fit a hook or a hand is often decided on the basis of the amputee's sensitivity. Those particularly sensitive about their amputation might be expected to reject a hook because of its appearance. The majority of the amputees in this study (61 percent) said that they believed hooks to be mechanical-looking but not unsightly, while a significant additional number (25 percent) expressed a more negative attitude concerning their appearance. But only

1 percent said they would not use one under any condition:

I THINK THAT A HOOK IS:

so ugly I would never wear one.	1%
so ugly I would never wear one when I'm with other people.	2
unsightly but not enough to prevent me from wearing one.	23
mechanical looking but not unsightly.	61
as natural looking as any artificial hand.	13

The composite data indicate that, although the amputees showed considerable awareness of their appearance, they did not brood about it. When asked directly, they were much more likely to deny being sensitive than to admit being preoccupied with their condition. They were well aware that amputations and prostheses arouse curiosity, but they maintained that they (the amputees) were "normal" and so did not feel resentful toward these attentions. Amputees who do acknowledge self-consciousness are most likely to do so in situations where there is no social pressure against displaying sensitivity.

On the basis of other evidence, there seems to be considerably more indication of sensitivity and of hostility toward the curious person than is revealed by the questionnaire. This is to be expected, for clinical situations induce greater rapport and permit the amputee to express hostile feelings with less fear of social criticism. Thus, it is quite likely that the amputee's sensitivity is much greater than he is willing to admit.

The universal unwillingness of amputees to admit that they differ from others rests in part on the fact that in many respects they are indeed no different from other people. But it also may represent a "whistling-in-the-dark" attitude, an attempt to deny something that the amputee really believes to be true (*e.g.*, that he *is* handicapped or inferior), and may reflect the amputee's resistance against the social consequences of being "different."

As has already been mentioned, amputees are likely to incorporate the negative attitudes of others into their own self-concept. Most amputees recognize that nonamputees are more comfortable when the fact of amputation is not conspicuous, and they will attempt by various means to "spare the feelings" of others by trying to reduce the visual "shock" for the nonamputee. Many of the subjects are not, however, merely responding appropriately to social cues but rather are using this explanation as a rationalization for their own self-rejecting thoughts. The same self-rejection may be responsible for the denial of sensitivity, which the questionnaire data show to be characteristic of a sizable minority of the sample.

APPRAISAL OF ACCEPTANCE BY OTHERS

"Appraisal of acceptance by others" refers to the amputee's evaluation of the effect his disability has on the approval others may give him. Less than 5 percent of the amputees said that they felt they were being treated any way different from that in which they had been treated before amputation. Almost all of the subjects claimed that their amputation had had little or no effect upon their acceptance by others. They rejected overwhelmingly the suggestion that their amputation merited them either special treatment or discrimination in their job, family, or social relationships. Most of them said they did not feel that people paid them undue attention. In general, the data indicate that amputees feel they receive sufficient but not excessive attention in social situations. A small percentage admit that some sympathetic behavior is displayed consistently in their job and family relationships.

The amputee claims to be accepted by others on the same basis as anyone else, and he rejects strongly the suggestion of "different" treatment. But he will more readily admit to being favored than to being rejected. The treatment program seemed to bring a slight increase in the number of those who felt they were accepted on the same basis as other people. But little change was noted among those who claimed to be the recipients of either favoritism or antagonism. The data suggest that the treatment program was psychologically beneficial to those who were "uncommitted" on the first testing but that it had no effect on those who were convinced of their "different" status.

The cumulative evidence about the social

position of the disabled person strongly suggests that the results of the survey again represent the amputees' *wishes* rather than the actual situation, a finding supported by the fact that, when asked indirectly how they thought amputees should be treated, the majority revealed that they preferred to have little made of their physical handicap:

IF YOU WERE A NONAMPUTEE, HOW WOULD YOU REACT TO AN AMPUTEE?

I would ignore the fact that the person is an amputee.	16%
I would treat him as a normal person who just happens to have lost an arm or hand.	72
I would expect less from him physically.	6
I would be more kind and thoughtful of his feelings.	5
I would know that, as an amputee, he requires special treatment.	1

SOCIABILITY

"Sociability" refers to the extent to which the amputee seeks, and derives pleasure from, social relationships. In this connection, the subjects said that they looked forward to social functions and enjoyed them. The treatment program had the effect of increasing by about one fourth the number of amputees who said that they "always" enjoyed these functions. All but a very few of the subjects said that they had greater social confidence with their new prostheses. Neither before the treatment period nor after, however, did more than 5 percent confess to any lack of social confidence. Over three quarters of the amputees said that neither their amputations nor their prosthesis-wearing had caused any change in their social relationships. Those who did report changes were almost unanimous in claiming that the changes were toward greater sociability.

These results reaffirm the earlier observations that the amputee tends to deny he has any major problems of acceptance. He usually claims that he engages in social activities eagerly and freely and experiences no prejudice because of his disability. But here again it is possible to read these results as expressing not so much the real facts as the wishes of the amputee to be accepted fully into the nonamputee world. Nevertheless, the indications are clear that the amputee tends to have more social confidence after suitable prosthetic fitting and treatment, the implications being that superior prosthetic equipment provides the basis for the ability to meet others with less trepidation and with greater feelings of personal adequacy. It also confirms indirectly the significance of feelings of functional adequacy and of ability to be independent.

FRUSTRATION

"Frustration" refers to the amputee's experience resulting from his inability to achieve personal, social, and vocational goals because of his amputation. The term refers both to whatever blocks or interferes with the amputee's strivings and to his subjective feelings of annoyance, confusion, or anger when he is thwarted. While 58 percent of the amputees said they rarely or never were prevented from achieving their goals, the other 42 percent claimed to feel frustrated from time to time as a result of amputation:

DOES BEING AN AMPUTEE PREVENT YOU FROM DOING THINGS YOU REALLY WANT TO DO?

Never	20%
Very rarely	27
Rarely	11
Sometimes	37
Frequently	5

When, however, absence of a limb prevented performance of a task, a considerable proportion of the amputees (86 percent) felt annoyed. They almost unanimously (98 percent) said that they did not give up trying to do something because it was difficult, or that they gave up only after repeated failures.

As for vocational goals, a majority of the amputees refused to admit more than slight difficulties. Some 40 percent indicated that there was some substantial interference:

DO YOU FEEL THAT YOUR AMPUTATION INTERFERES WITH YOUR GETTING A JOB?

Not at all	27%
Very slightly	15
Slightly	18
Somewhat	29
Seriously	11

Here the fact that the more seriously disabled (bilateral and shoulder-disarticulation cases) responded as did the other amputees seems to suggest that the results do not accurately reflect the real situation.

The relatively small degree of frustration the amputees reported is surprising in view of the many frustrating situations they encountered. It suggests that many of the responses were given because they seemed socially desirable and because the test situation did not encourage the amputee to express freely his aggressive or negative feelings. But it is also possible that repeated experiences of frustration, together with the strong motivation to be "like anyone else," which is so characteristic of the subjects studied, can produce in many amputees a truly high level of frustration tolerance. To this must be added the active efforts to avoid situations potentially frustrating.

Any interference with goal-directed activity constitutes a frustration. But interpreting frustration in others has certain dangers because what frustrates one individual may not frustrate another. The nonamputee who fails to consider this circumstance is likely to make toward the disabled person unnecessary offers of help. The amputee may take such overtures as indicating that people believe him to be incompetent and may, consequently, feel downgraded in his status as a functioning person. In a sense, the real frustration in this particular situation is the nonamputee's lack of awareness of the amputee's competence.

The intensity of an amputee's frustration depends upon how important his thwarted goals are to him. And while he may not feel seriously deprived if he cannot accomplish some trivial task, his frustration may be great if the particular failure happens to symbolize his inability to reach some more important goal. A minor frustration may assume importance if it symbolizes a general downgrading of status. Furthermore, when frustration is chronic the setting is ripe for the development of neurotic symptoms that represent the amputee's attempt to escape from an intolerable situation. It is considerably easier for anyone to deal with a short-term frustration than to adapt to a long-term one. Amputation is permanent and hence can lead easily to chronic frustrations and to neurotic solutions for the frustrations.

The amputees in question showed two general types of reaction to frustration. One was concerned with overcoming the obstacles that interfere with the attainment of goals. In the other, the concern had more to do with preserving self-esteem and warding off anxiety than with achieving thwarted objectives. The first, or goal-directed, reaction to frustration is characterized by the amputee's ability to accept the reality of his amputation with a minimum of self-deception. In this type of reaction, the amputee seeks goals that are in line with his reduced capabilities and takes whatever steps he must to overcome the barriers imposed by his amputation. When questioned, he admits to being frustrated sometimes, but he shows a high toleration for frustration and tends to give up only when a task is clearly beyond his abilities, at which time he is willing to accept appropriate help. Besides, he will probably accept himself as a person and neither brood over nor resent his situation.

In the second, or "ego-protective," reaction to frustration, the amputee refuses to accept reality. Instead, he distorts it and tries to create situations in which he can be at ease and relatively free of anxiety. If necessary, he will go so far as to deny his disability. He tends to set such low limits for achievement that he can avoid frustration, and he often sharply restricts his involvement in life as he seeks to eliminate opportunities for frustration. Such protective action is likely to lead to neurotic symptoms—to hypersensitivity, invalidism, defeatism, somatic complaints, anxiety, social withdrawal, and so on. In an earlier publication, Siller (*8*) observed that amputees who achieved good adjustment were often strongly oriented toward compensating for their loss. They were, in other words, showing a goal-directed reaction to frustration. It was also observed that amputees who adjusted poorly often directed their efforts toward avoiding the implications of their loss, thus showing an ego-protective reaction to frustration.

As a result of the treatment program in the

NYU Field Studies, there was a small increase in the number of amputees who reported a moderate degree of frustration tolerance combined with the ability to recognize their limitations clearly. While in answering the test questions the amputees undoubtedly had a tendency to deny unfavorable feelings and behavior, the subjects as a whole still showed a rather high tolerance for frustration.

OPTIMISM

"Optimism" refers to those feelings of adequacy, of self-confidence, and of positive future outlook that the amputee experiences. The negative aspects of this personality variable are pessimism, depression, and feelings of inadequacy and inferiority. While the subjects in the study tended to stress their positive feelings of optimism and to de-emphasize their pessimistic feelings, few denied that they experienced depression at times:

HOW OFTEN DO YOU FEEL "DOWN IN THE DUMPS" OR "BLUE"?

Frequently	3%
Sometimes	29
Rarely	21
Very rarely	39
Never	8

The treatment period had the effect of increasing from 33 percent to 39 percent those amputees who answered "very rarely," and in general the fitting of new prostheses increased slightly the claims of optimism. Most of the amputees professed to be very optimistic about their future prospects, and none at all said that they expected to be unsuccessful:

DOES YOUR FUTURE PROMISE TO BE:

extremely successful?	14%
moderately successful?	66
slightly successful?	11
neither successful nor unsuccessful?	9
unsuccessful?	0

Throughout the questionnaire, the subjects tried to avoid responses indicating pessimism, depression, and feelings of inadequacy or inferiority. They were more likely to admit feelings of superiority than of inferiority, but in general they avoided admitting extreme feelings in either direction:

DO YOU EVER HAVE FEELINGS OF:

Inferiority?		*Superiority?*
38%	Never	29%
28	Very rarely	22
12	Rarely	15
20	Sometimes	30
2	Frequently	4

The amputees tried of course in their answers to place themselves in a socially favorable light—to shun answers with negative implications. But we may still estimate the feelings of the average amputee. He resists, rejects, and resents any suggestion that as a person he differs from anyone else; at the same time he acknowledges some (but not too much) physical difference and handicap. If he senses that the nondisabled people about him consider him "different" because of his loss, he may often go to extremes to deny pessimistic feelings which in a more relaxed environment he might well acknowledge.

Amputees are not alone in their desire to be placed in a favorable light. The tendency to respond in a socially desirable manner seems to be characteristic of all groups when tested under conditions similar to those of the present study. Nevertheless, when we consider the very real handicaps amputees must face, we may conclude that those studied here are for the most part maintaining an optimistic outlook.

Social and Functional Factors in Prosthetic Wear

The attitudes of amputees toward prostheses have in the past received little systematic study. The amputee's preferences in artificial limbs, and his habits in using them, are evidently not based entirely upon his objective assessment of his functional and social needs. They are influenced also by emotional factors arising from the meanings he attaches to the wearing of artificial limbs. Little organized information is available about these attitudes, whether rational or irrational, and we know little as yet about the specific effects that an amputee attributes to his prosthesis once he has accepted and worn it. What difference does he think it makes in his daily life?

The prosthetic-reaction test (Appendix IIIG), designed to explore in a systematic way some of the attitudes and reactions underlying prosthetic wear, attempted to gauge, in various situations, the amputee's response, both when he is considered to be *wearing* an artificial arm and when he is considered *not* to be wearing one. In a series of nine different pictures, a fictitious amputee, "John," was shown in some everyday situations—some in which his sensitivities as an amputee might be expected to be aroused. Below each picture were from five to nine statements indicating possible responses that John, the amputee in the picture, might make to the situation depicted. The subjects under test were asked to select the statement most nearly describing what John might say, feel, or do in each case. The assumption, of course, was that the amputees would attribute to the imaginary John some of their own feelings and reactions. It was thought that, as the amputees thus responded to specific life situations through the medium of this other person, their attitudes might be expressed more freely than they would be through direct questioning.

The test was administered to each of the amputees three times, once at the beginning of the research program (Evaluation I) and twice at the end of the studies (Evaluation II). In Evaluation I, and at the first administration during Evaluation II, the subjects were asked to select John's response "*if he were wearing a prosthesis as he usually does.*" Immediately after the amputees had completed the test for the first time during Evaluation II, they took it again but now were asked to select John's response "*if he never wears a prosthesis.*" For convenience, we shall refer to these three administrations of the test as E1, E2a, and E2b. Together, the three provide data for the study of three major questions:

1. In the difficult social situations that an amputee faces daily, what are his most frequent responses and his most commonly held attitudes?

2. What changes, if any, in his attitudes and reactions came as a result of his being fitted with a new prosthesis and taking part in the research program?

3. In these difficult social situations, how does the wearing of a prosthesis affect the amputee's responses?

Each of these problems shall be taken up in turn.

The prosthetic-reaction test touches upon a number of aspects of an amputee's performance. Foremost is the general area of "security," which involves the amputee's basic acceptance of himself and others, particularly his personal adjustment to the loss of his arm. Included within the concept of security were such constructs as self-acceptance (the ability to view the loss without self-pity, exaggeration, or denial, and without resorting to maladaptive means of defending self-esteem) and reality-facing (the ability to appraise environmental situations as they are). In addition, there was evidence that several of the cartoons strongly measured a second variable, "independence," which describes the amputee's motivation to be self-sufficient and to function adequately with a minimum of assistance.

Psychologically, strivings for independence are likely to stem from the individual's feelings of security, and as such the two must be considered related phenomena. But since the need to be independent is a major concern of amputees, separate analyses of the data concerning independence were made whenever appropriate. Each statement in the test was therefore rated first for "security" and, when indicated, for "independence." Four psychologists ranked from 1 to 5 all possible responses according to the extent that the individual variables were reflected therein.[4] Personal differences in ranking were resolved through mutual discussion among the four.

Responses rated 1 or 2 were considered "high." A rating of 3 was considered "intermediate," a rating of 4 or 5 as "low," and the terms "high," "intermediate," and "low" were used as relative terms to describe the individual's position along the "security" and the "independence" scales. For example, Picture VI (Appendix IIIG) showed an amputee in a restaurant with a steak that seemed too tough for him to cut. The seven statements given beneath the picture were ranked and judged as shown in the following tabulation:

[4] Six of the nine cartoons portrayed situations not relevant to "independence" and were therefore rated for "security" only. See Table 1, page 102.

Statement	Analysis	
	Security Rating	Independence Rating
1. I'd have to have it cut for me.	2 (high)	5 (low)
2. I'd try, and if I really couldn't manage, I'd ask to have it cut.	1 (high)	2 (high)
3. I'd manage with it.	3 (intermediate)	1 (high)
4. Isn't it awful not to be able to manage? I'd like to do this alone, but I'm afraid I need your help.	4 (low)	3 (intermediate)
5. I'd try and then if it were too tough I'd ask to have it cut.	2 (high)	2 (high)
6. (I couldn't manage, John thinks to himself.) Take it back. This is much too tough.	5 (low)	1 (high)
7. My companion would feel embarrassed, but I would have to have it cut.	4 (low)	4 (low)

The prosthetic-reaction test, then, tells us how amputees appraise various social situations and what they think about the worth of artificial arms in these situations. It also gives us some indication of their feelings of independence and security, both when they are wearing prostheses and when they are not. What light does this information shed upon the three major problems already mentioned?

AMPUTEE RESPONSES TO EVERYDAY SOCIAL SITUATIONS

The most outstanding finding of this study was that the amputees overwhelmingly—in fact, almost invariably—selected the most positive responses to the situations depicted in the cartoons, particularly when the amputee was assumed to be wearing an artificial arm. For almost every situation of the series, the statement most frequently chosen was one extremely high in both independence and security. Moreover, for most of the pictures well over half the sample responded with statements that were judged "positive" (*i.e.*, high in security or independence). Even in E2b, where positive responses were considerably fewer, they still accounted for a large segment of the sample. Typical percentages of amputees showing high, intermediate, and low "security" and "independence" responses to each cartoon are shown in Table 1, where the data are derived from E2a (post-treatment) and refer to circumstances in which John was supposed to be wearing a prosthesis. For the sample as a whole, there were negligible differences between the E1 (pretreatment) and the E2a (post-treatment) data.

For every situation, more than 60 percent of the sample chose positive responses, and in only one instance did more than a negligible proportion choose a statement reflecting definite insecurity. As for that item, many of the respondents had not correctly interpreted the other person to be the amputee's wife. Even more striking is the fact that from a fourth to a half gave as their response the single most positive statement. It is clear, then, that the majority of the amputees wished to be viewed as functionally independent, having confidence in their ability, with a desire to demonstrate their functional achievements, and willing to accept some aid if it is found to be needed. The vast majority of the responses expressed an acceptance of the loss of the limb, a willingness to discuss the amputation with others, and a general self-assurance in social situations.

In general, the most popular responses were those which emphasize functional effectiveness, self-confidence, and lack of sensitivity about amputation. Reactions suggesting any admission that the amputee considered himself at all "different" from anyone else were extremely rare. It seems clear that the subjects readily recognized the socially desirable responses and favored them overwhelmingly. To what extent this eventuality represents the

Table 1

DISTRIBUTION OF AMPUTEES' "SECURITY" AND "INDEPENDENCE" RESPONSES

Independence (%)			Situation	Security (%)		
High	Inter-mediate	Low		High	Inter-mediate	Low
—	—	—	Amputee is confronted with an acquaintance who asks him how he likes his new arm.	79	15	6
—	—	—	Amputee is being looked at in public by a stranger.	88	7	5
—	—	—	Amputee is applying for a job.	80	8	12
—	—	—	Amputee approaches a woman at a dance.	83	9	8
—	—	—	Amputee is being questioned by children.	83	10	7
—	—	—	Amputee is meeting a woman, usually taken to be his wife, after leaving the hospital.	63	12	25
60	23	17	Amputee is being served coffee and cake at a social gathering.	74	20	6
87	2	11	Amputee is served tough steak in a restaurant with a companion.	71	27	2
65	5	30	Amputee is dressing at home in presence of his wife.	80	18	2

true feelings and behavior of the group, and to what extent it represents wishful thinking, cannot be determined from these data—a situation that reflects a weakness in the prosthetic-reaction test as currently conceived. Evidence indicates that amputees are very much concerned with conforming to the important cultural values of self-reliance and self-confidence and that they abhor any suggestion of a departure from complete normality.

CHANGES IN RESPONSES AS A RESULT OF FITTING

For the group as a whole, there were virtually no significant differences between E1 and E2a, even though the latter was administered after a considerable period of time had elapsed. This result would suggest that the treatment program had little or no effect on the expressed attitudes of the group. But when we consider separately those amputees who were being fitted for the first time and those who had worn prostheses before, some changes can be detected among the new wearers. Since the number of amputees being fitted for the first time was small (only 55), no extensive quantitative analysis can be made. Nevertheless, a few general conclusions can be drawn.

First of all, the responses after fitting indicated that new wearers were slightly disappointed in the functional efficacy of their artificial arms. While initially (on E1) a large number of these amputees revealed expectations that the prosthesis would enable them to do "almost everything," particularly in their occupational roles, the E2a responses indicated more modest attitudes. But these changes were not toward more negative responses. Rather, they reflected the fact that the amputees concerned had indulged in unrealistic expectations for the prostheses and then had adjusted to a more realistic view after some experience with their new arms. There were, moreover, indications of a greater degree of security in social situations. After fitting, some of the new wearers indicated an increased acceptance of their amputation—a greater ability to talk about it, less tendency to withdraw from situations revealing the disability, and less expectation of pity from others. Besides this, they expressed a greater readiness to ask for help without apology or embarrassment.

EFFECTS OF FITTING UPON RESPONSES TO EVERYDAY SITUATIONS

As has already been indicated, the primary aim of the prosthetic-reaction test was to evaluate the amputee's feelings about the part that an artificial arm plays in the common

difficult situations of his life. The statements the subjects chose as describing John's behavior may therefore be taken as reflecting aspects of their own behavior. Consequently, if we compare the results of E2a (in which John is considered to be *wearing* a prosthesis) with those of E2b (in which he is considered *not* to be wearing one), both tests having been administered at the end of the studies, we discover some of the effects that wearing an artificial arm has on the daily life of an amputee. Toward this end, the two personality variables, independence and security, were considered. In separate analyses of the data from the "nonprevious prosthesis wearers" (referred to as NPPW's) and the "previous prosthesis wearers" (PPW's), it was found that the two groups did not differ in their responses except as discussed specifically hereafter.[5]

A review of the E2a (prosthesis worn) and E2b (prosthesis not worn) responses follows:

SITUATION: Amputee is being observed in public by a stranger.

	SECURITY[a]	
	High	*Low*
E2a	88%	5%
E2b	70	21
Change	18	16

[a] The percentages indicated in this and related succeeding tables reflect the proportion of the total sample expressing either high or low responses. Intermediate, or neutral, responses are indicated by difference.

Greater tolerance of curious strangers is exhibited when a prosthesis is worn. In E2a the amputees appear better able to view the situation without misinterpretation, to be more sure of themselves and less likely to pity themselves or to expect pity from others. The PPW's are somewhat more secure in the E2a situation than are NPPW's, even though both groups were wearing prostheses at the time of the tests. The most reasonable explanation for this difference would seem to lie in the fact that the period of prosthetic wear for the NPPW group was insufficient for feelings of conspicuousness to disappear.

[5] It should be remembered that on the average E2 was administered about six months after fitting. It is probable that, had this test been administered to the NPPW's before they received and used artificial arms, considerably greater differences between PPW's and NPPW's would have been found.

SITUATION: Amputee, applying for employment, is asked how he would handle the job.

	SECURITY	
	High	*Low*
E2a	80%	12%
E2b	63	25
Change	17	13

There is a much greater tendency for the amputee to take a positive, constructive attitude and to demonstrate his qualifications when he is wearing a prosthesis than when he is not. The PPW's also tend to see the prosthesis-wearer as less aggressive and less apologetic than do the NPPW's.

SITUATION: Amputee at a dance, wonders whether or not to ask a woman to dance and, if so, whether or not to mention his amputation.

	SECURITY	
	High	*Low*
E2a	83%	8%
E2b	75	22
Change	8	14

There is a greater expectation of rejection when the amputee is not wearing a prosthesis. An amputee who wears an artificial arm is apparently more willing to approach a strange woman without apology and invite her to dance.

SITUATION: Amputee sees children approaching and wonders what to say if they ask about his amputation.

	SECURITY	
	High	*Low*
E2a	83%	7%
E2b	62	25
Change	21	18

The subjects apparently felt that an amputee wearing a prosthesis is less likely to try to withdraw from the fact of his loss and is more able to accept his disability without self-pity. When the amputee was portrayed as having a prosthesis, almost all chose the response which explains that the hand was lost and shows how the artificial one works. Without a prosthesis, the amputee gives as his most frequent response, "I'll tell them I lost my hand," thus reflecting the prestige value of the prosthesis.

SITUATION: Amputee is meeting a woman (usually taken to be his wife) upon his departure from the hospital and wonders what to say to her.

	SECURITY	
	High	*Low*
E2a	63%	25%
E2b	53	46
Change	10	21

Interpretation of this item is difficult because, while most of the subjects understood the woman to be the amputee's wife, others did not. The specific answers make clear that the amputee who wears a prosthesis is less likely to avoid the subject of his amputation than is the amputee without an artificial arm.

SITUATION: Amputee is offered coffee and cake by a hostess who knows nothing about him.

	SECURITY		INDEPENDENCE	
	High	*Low*	*High*	*Low*
E2a	74%	6%	60%	17%
E2b	57	12	46	26
Change	17	6	14	9

Wearing the prosthesis is associated with greater functional independence and increased feelings of security (*i.e.*, by more ability to recognize the inescapable limitations inherent in the situation).

SITUATION: Amputee, in restaurant with companion, is served steak that looks too tough for him to manage.

	SECURITY		INDEPENDENCE	
	High	*Low*	*High*	*Low*
E2a	71%	2%	87%	11%
E2b	79	8	59	38
Change	8	6	28	27

Again, the amputee wearing the prosthesis is thought to be better able to handle the situation and less likely to be dependent upon others. In this instance the functions afforded by the prosthesis have a clear-cut influence on feelings of independence.

SITUATION: Amputee is at home with his wife and wants to unbutton his cuff.

	SECURITY		INDEPENDENCE	
	High	*Low*	*High*	*Low*
E2a	80%	2%	65%	30%
E2b	72	5	42	51
Change	8	3	23	21

Both PPW's and NPPW's seem to feel that a prosthesis wearer is more willing to make a reasonable effort to help himself. Those in the NPPW group also express less of a tendency to apologize for themselves when wearing the arm.

Differences between the E2a (with prosthesis) and E2b (without prosthesis) responses were considerable throughout the entire test, both for amputees who were being fitted for the first time and for those who had previously worn prostheses. We may thus conclude that the positive acceptance of prostheses reflects not merely the enthusiasm of new wearers but rather the genuine value of prosthetic wear in its own right.

The indications are clear that amputees regard a prosthesis as a definite asset in functionally demanding situations and that they think of it as something enabling them to be more independent, more secure, and more willing to accept their condition. In the potentially threatening situations that an amputee must face from time to time, a prosthesis contributes to his ability to handle himself easily and self-confidently, even in cases where the prosthesis does not have immediate functional value.

The data for "emotional" situations indicate that the amputees' positive expressions of security were definitely greater when the protagonist was wearing a prosthesis than when he was not. An artificial arm apparently gives many amputees an increased confidence in their functional adequacy. This in turn helps them to achieve a greater self-acceptance, enables them to face their disability more realistically, and lets them view the reactions of others without feeling quite so threatened.

Of the two personality variables considered, independence and security, independence appears to be the more strikingly affected by prosthetic restoration. The subjects tend to expect that the amputee who wears a prosthesis will be more effective functionally, more self-sufficient, and generally more adaptive than the nonwearer. When the matter of security is concerned, the role of the prosthesis is less pronounced. Still, most of the amputees think of prosthesis wearers as more self-accepting, less shy, and less easily embarrassed than nonwearers.

The responses to the prosthetic-reaction test strongly indicate that amputees feel there is both functional and psychological advantage in the wearing of a prosthesis. They consistently attribute more positive responses to the amputee wearing an artificial arm than they do to the nonwearer in the same situation. But of course all of these findings are merely projections upon a fictitious amputee pictured in a cartoon; we do not yet know the precise extent to which these projections reflect the actual responses amputees make in life situations. Nevertheless, it is clear that the wearing of a prosthesis has a positive effect upon the way an amputee perceives and reacts to many social situations in his daily life.

Attitudes Toward Prosthetic Wear, Before and After Fitting

The discussion thus far indicates that the amputee believes strongly in the importance of wearing an artificial arm. He tends to feel

that a prosthesis increases his functional capabilities and helps him to cope with social situations. He retains these beliefs, even reinforces them, after participating in the research program. To analyze still further amputee attitudes toward the wear and use of a prosthesis, additional studies were designed to seek answers to the questions *Are the expectations of nonprosthesis wearers fulfilled by a prosthesis?* and *Can the postfitting attitudes of amputees toward their prostheses be predicted on the basis of their prefitting expectations?*

As for the first of these queries, the amputee who does not wear a prosthesis holds certain preconceived opinions about the value of an artificial limb before he ever undertakes to wear and use one. If these expectations are fairly realistic, his experience with his prosthesis may be gratifying. But unrealistic expectations can interfere with the successful wearing of a prosthesis. For this reason, a study was made of the alterations in attitudes of nonwearers after they had used a new prosthesis. As for the second question, it is reasonable to expect that the opinion an amputee holds about prostheses before he receives one will be related to his opinion after he has been fitted. If these relationships are stable enough to be predicted, potential problems may be anticipated and perhaps avoided. It is well known that a negative attitude on the part of an amputee interferes with his wholehearted participation in the rehabilitation process and thus reduces the probability of success. Identifying such a situation is the first step toward correcting it.

ARE THE EXPECTATIONS OF NONPROSTHESIS WEARERS FULFILLED BY A PROSTHESIS?

Among the subjects for whom data were available in this aspect of the study were 45 amputees who had never worn prostheses before their participation in the research program. About half of them were relatively "new" amputees who at the time may not yet have had an opportunity for fitting. The other half consisted of persons who had been amputees for from one to 27 years and who were therefore considered to have had ample opportunity to obtain prostheses had they wanted to. Although it is possible that some in the latter group may have been discouraged long ago by the lack of adequate prostheses for shoulder disarticulation and for certain other types of amputation, some had stumps relatively easy to fit, and accordingly factors other than lack of prosthetic equipment seem to have been present.

Because this study was only one phase in a more general investigation of the conditions underlying the wear or nonwear of a prosthesis, use was made of a broad approach in which was collected information generally related to amputation and to prosthetic restoration. Gathered by means of a questionnaire probing prior beliefs and attitudes on a variety of matters relating to prostheses (Appendix IIIH), the data sought included sources of prosthetic knowledge and an estimate of its extent, functional expectations, opinions of the appearance of prostheses, opinions of the comfort of prostheses, attitudes toward prosthetic training, attitudes toward the general value of artificial arms, and anticipated difficulties with prostheses. Approximately six months after the fitting of a prosthesis to these patients, the questionnaire was given again to obtain postfitting attitudes.

Sources of Prosthetic Knowledge and Estimate of Its Extent

The extent of prosthetic knowledge claimed by the subjects increased only slightly after they had participated in the program. Before fitting, 95 percent said they knew little or nothing about artificial arms; after fitting 85 percent still said so. Even after some six months of having worn prostheses, only 14 percent said they knew "much" about the subject. These findings may of course only reflect restraint and modesty. If they reflect the situation accurately, the amputees are indeed poorly informed. To determine whether the sources of information had any bearing on the state of amputee enlightenment, the subjects were asked to name their principal source of information.

As can be seen in Table 2, the answers were rather diverse. Mentioned were five major sources of information before fitting. Three of these (other amputees, friends, self) are generally unreliable in matters of prosthetics.

Table 2
SOURCES OF PROSTHETIC INFORMATION
(Entries represent number of times mentioned.)

Prefitting		Postfitting
19	Physicians	3
19	Other amputees	0
14	Myself	13
13	Prosthetists	9
11	Friends	0
1	Medical personnel (PT, OT, Nurse)	18
3	No one	0

Friends and one's own self are hardly qualified without special training, and other amputees, as has been indicated already, are not necessarily well informed. Medical personnel, including physical therapists, occupational therapists, and nurses, were cited by only one amputee as a source of information. But after the amputees had participated in the program, the picture changed sharply. Then most of them mentioned medical personnel as the main source of information, while "other amputees" were not mentioned at all.

Although the extensive list of pretreatment sources of information may indicate that the amputees were alert, receptive, and inquisitive, seeking information from all quarters, it may on the contrary mean that they used all these sources because they were not given information by those most competent to provide it. The general impression is that adequate information about prosthetics is not readily available to the average amputee and that there is therefore a real need for a more thorough prosthetics education of medical personnel. We might even suggest that more attention be given to improving knowledge of prosthetics among new amputees. One approach would be to furnish literature portraying different types of prostheses—along with a sober appraisal of the utility, as well as of the disadvantages, of current prosthetic equipment. Doing so would help the patient to acquire more realistic expectations, to eliminate some of his trepidation, and to fill his individual needs more successfully.

Functional Expectations

Experience tends to modify any overly ambitious ideas the amputee may have about the value of the prosthesis. Most of the amputees in the study had more realistic expectations after they had been fitted with their artificial limbs than before:

OPINIONS OF PROSTHESES BEFORE AND AFTER FITTING

Essential		Of Some Help		Of No Help	
Prefitting	Postfitting	Prefitting	Postfitting	Pre-fitting	Post-fitting
73%	51%	24%	34%	3%	15%

The 73 percent who before fitting said they believed prostheses were essential included 21 percent who said they thought artificial arms were "as good as normal limbs." Among those who after fitting said they believed prostheses to be very important, there were still 10 percent who said they thought their prostheses were as good as normal limbs. Apparently the fitting of the prosthesis reduces the number of amputees who deny reality but does not eliminate that group completely.

Before they were fitted, the amputees tended to expect that artificial limbs would take a considerable expenditure of energy for effective operation, but experience showed them that these estimates had been too pessimistic:

AMPUTEES' ESTIMATES OF EFFORT REQUIRED TO OPERATE AN ARTIFICIAL ARM

Prefitting		*Postfitting*
78%	A great deal of effort	38%
18	A little effort	33
4	Hardly any effort	29

Those who deal with prospective wearers should make use of the general tendency among amputees to believe that prostheses are helpful. But unless the limitations as well as the advantages of artificial arms are explained, false hopes and unreasonable expectations will result.

Opinions on the Appearance of Prostheses

Judgment of appearance is a complex and subjective process. The phrase "acceptable ap-

pearance" means many things to many people because the component factors are not often defined. In this study, three factors were identified. The first relates to the appearance of the prosthesis itself—to the degree to which it resembles the natural limb. The second relates to the readiness with which the artificial limb is recognized by observers. And finally the third relates to the appearance of the prosthesis when it is actually in use by the amputee.

Roughly 75 percent of the subjects said they believed that their prosthetic arms and hands closely resembled normal limbs. Although the remainder said they found no strong resemblance, it was clear that in general the amputees accepted the appearance of their prostheses. One patient alone gave "unfavorable appearance" as the reason for not wearing a prosthesis.

At this point it is perhaps worth noting that medical personnel who see many varieties of prosthetic equipment tend to develop, out of their own experience, personal sets of standards about the appearance of prostheses and sometimes impose these standards upon an amputee. But the patient, having had very little experience with prostheses, bases his opinions on quite personal factors, and these may be at great variance with those which influence the judgment of the clinic team. We must therefore strive to fulfill the actual needs of the individual amputee rather than to satisfy our own honest but at times inappropriate standards.

Initially, most of the amputees said they expected to be recognized as amputees even when wearing prostheses, an expectation apparently confirmed by experience:

WHEN I WEAR AN ARTIFICIAL ARM, PEOPLE:

Prefitting		*Postfitting*
46%	still know I'm an amputee.	43%
45	rarely mistake me for a nonamputee.	43
4	sometimes mistake me for a nonamputee.	2
5	frequently mistake me for a nonamputee.	12
0	never know I'm an amputee.	0

These findings are especially interesting when we recall that about 75 percent of the amputees said they thought their prostheses closely resembled natural arms and hands. Yet only a few of the subjects, either before or after fitting, said that they believed they could be taken for nonamputees. It seems apparent, therefore, that more than just the physical appearance of the artificial arm was involved. A strong similarity may be thought to exist, but generally the amputee does not believe similarity alone will enable him to pass as a nonamputee.

Data from studies by Dembo and Tane-Baskin (*3,7*) on the noticeability of a cosmetic glove indicate that noticeability depends upon the "intensity" of the situation, that is, upon the closeness of the amputee's social and physical contact with others at any particular time. In view of this observation, it is clear that the inability to discriminate between situations of varying intensity keeps us from interpreting the present data any further. The amputees' responses in the study came from their experiences in both casual and intense situations, and we cannot distinguish between the two.

Ease and smoothness of operation constitute another important factor in the general appearance of the amputee. The well-trained, smoothly functioning amputee contrasts strongly with a less-trained, uncoordinated, and awkward one. Full evaluation of appearance must, therefore, also take into account the dynamic factor, the impression given by smooth, normal-appearing movement as contrasted with that given by halting, uncoordinated motions.

We see, then, that there are at least three important considerations involved in any judgment of an amputee's appearance—the actual appearance of the prosthesis apart from its functioning (the "static factor"), the naturalness with which the prosthesis is used (the "dynamic factor"), and the intensity of the amputee's situation (the "situational factor"). Treatment personnel usually place greatest emphasis on the appearance of the limb itself; the amputee may base his impression more upon the other two considerations.

Opinions on the Comfort of Prostheses

The amputees' statements about the comfort of artificial limbs did not change very much

with experience. Both before fitting and after some period of wear, about 25 percent of the subjects claimed considerable discomfort, while 50 percent or better had no complaints on this score:

CHANGE IN ATTITUDES TOWARD COMFORT OF PROSTHESES

Prefitting		*Postfitting*
62%	Comfortable	50%
14	Tolerable	24
24	Uncomfortable	26

For three quarters of the prosthesis users, comfort does not appear to be an important problem, and expectations of comfort seem to be borne out by actual experience. But the 25 percent who complained about discomfort *do* represent a very significant problem because discomfort is a common cause for rejection or infrequent use of artificial limbs.

At present, research aimed at eliminating discomfort focuses on prosthetic and physiological factors, an emphasis that seems appropriate in view of the fact that the principal objective causes of amputee discomfort are related to fit of the socket and harness and to weight of the prosthesis. But the problem has several other aspects, and these might also be explored profitably. There is for example the question of education—of how to prepare the amputee to expect at least some degree of initial discomfort. Another possible factor relates to the early use of the new prosthesis unwisely and too well. The mere statement, "At first this may be uncomfortable," may be insufficient warning for the new user. This phase of orientation needs more emphasis. Otherwise there is always the danger that amputees not fully aware of the difficulty of initial adjustment may give up with the feeling that prostheses are not for them.

In addition to all these matters, there are psychological problems related to the amputee's pain tolerance. The way the amputee reacts to pain is influenced by such psychological factors as his acceptance of the amputation and his unrealistic hopes for the prosthesis. Finally, there is a need to recognize the special social attitudes that an amputee elicits when he expresses discomfort.

Attitudes Toward Prosthetic Training

Training to operate a prosthesis effectively requires a period of time ranging from a few hours to many hours, as correctly anticipated by all but three percent of the subjects:

AMPUTEE ESTIMATES OF TRAINING TIME REQUIRED

Prefitting		*Postfitting*
72%	Many hours	70%
25	Few hours	30
3	Few minutes	0

As we have seen, the subjects of study generally knew little about the potentials of prosthetic restoration. When, on top of the amputee's functional disability, there is superimposed the unavoidably new and ambiguous situation, anxiety and feelings of dependency are created. Since at a number of points in the rehabilitation process the physical and occupational therapist is in closest contact with the patient and is offering direct functional assistance, he is one of the natural recipients of these negative reactions. It should be possible during training for the therapist to use these dependency feelings and other factors to instill in the patient an attitude of realistic independence. Moreover, the training situation offers the amputee opportunity to develop and to demonstrate his functional competence under professional guidance. Regulated training routines have many advantages. Learning is quicker and more efficient, and the number of successful experiences can be maximized while failures are held to a minimum. For the amputee, the training experience should result not only in proficiency with the artificial limb but also in a realistic functional independence and a general sense of adequacy and personal competence.

Attitudes Toward the General Value of Artificial Arms

In an effort to determine the significance that artificial arms had for the amputees, the subjects were asked to express their opinions in terms of three frames of reference—the advantages of using a prosthesis, the general functional help of a prosthesis, and the importance of the artificial arm.

Advantages. The overwhelming opinion among the amputees, both before and after fitting, was that artificial arms have more advantages than disadvantages:

OPINIONS OF ADVANTAGES OFFERED BY PROSTHESES

Prefitting		*Postfitting*
91%	More advantages	86%
5	No marked advantage or disadvantage	12
4	More disadvantages	2

General Help. The prosthesis enabled the amputees to get along better. Most of them maintained that they could get along *much* better. A few said that it hindered them slightly. No one said that it really interfered. But among the amputees who had expected to find extreme advantages, there were indications of marked changes of opinion. That the group with the highest expectations dropped from 78 percent to 59 percent illustrates the development of more realistic values through experience. The same kind of change is illustrated by the increase in the number of amputees who said they thought a prosthesis could help them to get along "about the same" or "slightly worse":

DOES YOUR PROSTHESIS PERMIT YOU TO GET ALONG:

Prefitting		*Postfitting*
78%	much better?	59%
18	slightly better?	13
4	about the same?	20
0	slightly worse?	8
0	much worse?	0

Importance. Despite a drop of 9 percent in the two most favorable categories of response, over 70 percent of the amputees said after fitting that they still believed it "very important" or "extremely important" for them to wear artificial arms. There was, however, an increase from 4 percent to 12 percent in the number of amputees who said they thought their prostheses "not at all" or only "slightly" important:

HOW IMPORTANT IS IT FOR YOU TO WEAR AN ARTIFICIAL ARM?

Prefitting		*Postfitting*
24%	Extremely important	27%
58	Very important	45
14	Somewhat important	16
4	Slightly important	8
0	Not important at all	4

It seems clear that the amputees retain favorable attitudes toward their prostheses after a period of wear. They appear to consider prostheses generally helpful, to believe that the advantages far outweigh the disadvantages, and to be convinced of the importance of artificial arms.

If these findings are accepted as showing the general feelings of the amputees, the next step is to relate these attitudes to the amputees' actual use of their prostheses. The relevant factors here are the amount and type of use, the situations in which prostheses are worn and employed, and the amputee's reasons for discarding a prosthesis.

Anticipated Difficulties With Prostheses

As regards the wearing of an artificial arm, the amputees foresaw certain difficulties. They anticipated problems in becoming accustomed to wearing the arm, in learning to operate it, in dealing with fatigue, and in avoiding awkwardness. With the exception of the second difficulty, learning to operate the arm, all of these turned out to be real problems, and some additional ones, such as mechanical failure of the prosthesis, stump pain, and excessive heat, developed.

The difficulties that amputees experience with their artificial arms range from relatively trivial annoyances to serious complications. Most of them may be placed in either of two categories—problems related directly to mechanical, functional, or medical disorders, and problems related to emotionally based preoccupation with conditions otherwise insignificant. Those in the first category disappear when the relevant conditions are corrected. Those in the second category reflect personality variations. In the interests of clarity and emphasis, these emotion-laden complaints have been classified in accordance with six hypothetical kinds of personality. Although having

no value in themselves the stereotypes thus created are not intended as "pigeon-holes," they serve nevertheless as organizing aids for identifying the problems.

The Unmotivated. The unmotivated amputee does not expend the effort necessary to overcome obstacles in using a prosthesis. The person without drive wears and uses his prosthesis so long as everything operates smoothly, but when even slight difficulties arise he lacks the motivation to continue with the limb and to expend any extra effort needed to operate it. Wear and use are thus limited. In justification of his action in discarding the prosthesis, the amputee may present many rationalizations in the form of spurious complaints about comfort and effectiveness.

The Ghost Story. Complaints derived from phantom sensation are likely to occur among amputees who are unaware of the common phenomenon and who consequently do not anticipate it. Still others, on experiencing the phantom, fall prey to misconceptions about it and fail to acknowledge the experience for fear of implying that they are disoriented or are suffering from mental disturbances. Through ignorance, such patients may attribute their phantom sensation or phantom pain to poorly fitting sockets or harnesses. Complaints usually disappear when the amputee has been well informed.

Mind Over Matter. People vary in the amount of discomfort they can accept. Since it is probably impossible to eliminate discomfort entirely, some dissatisfaction is inevitable. But this common difficulty may be reduced to some extent if, before fitting, the amputee develops realistic attitudes toward whatever discomfort he cannot escape. Forewarning the amputee may help him to avoid disappointment and exaggeration of his discomfort.

The Exaggerators. Some amputees tend to elaborate upon their complaints and to distort the situation out of all proportion to its real significance. They develop fixations about relatively unimportant details or symptoms, and they are not open to persuasion or logical argument. Most often such a complaint is based upon a personal need, as for sympathy or attention, perhaps only remotely related to the actual prosthetic condition. But until this personal need is satisfied, little success can be expected in handling the related prosthetic or medical conditions.

Motor Trouble. Difficulties associated with the actual operation of a prosthesis result from two conditions—from poor neuromuscular endowment, or from tensions and anxieties producing awkwardness and lack of coordination. In the first condition, the amputee possesses in balance and coordination basic deficiencies which together operate to reduce his functional potential. Owing to the effects of banging and twisting in awkward and erratic movements, the prospects of prosthetic maintenance tend to increase. In such a case, faults that are apparently prosthetic are really human faults.

The second condition typifies the anxious person who always anticipates something bad. He looks upon every squeak, every irritation, and every temporary malfunction as a sign that the prosthesis is falling apart or at least is in need of adjustment. He differs from the exaggerator in that his reactions are much more diffuse and not nearly so emphatic. Anxiety induces characteristic muscular tension, which interferes with function in much the same way as does an innate psychomotor inferiority. Since the latter condition offers a poorer prognosis and dictates a different course of care, it is necessary to make a distinction based upon etiology.

The Comparison Shopper. Every prosthetist knows of amputees who are always looking for something better. Sometimes such persons channel their needs constructively and make a contribution by entering the field of prosthetics development. More often, however, they dissipate their energies going from limbshop to limbshop looking for satisfaction they probably cannot get. These amputees are apt to become a matter of professional concern, for they often tend to depreciate the efforts, skill, and integrity of the art.

Recapitulation. It is likely that a single explanation runs through several of the foregoing categories, for the amputee's subconscious nonacceptance of his amputation may underlie lack of motivation, phantom sensation, over-reaction, and inability to be satisfied. The problems of phantom sensation

and of low discomfort tolerance may be accounted for physiologically, and the conditions of over-reaction and constant apprehension may be traced to personality factors more general than refusal to accept amputation. In any event, the categories can be made more useful, or at least revised constructively, if conceptual and experimental analysis is undertaken to establish the extent of each category, the etiological backgrounds, and the best manner of treatment in each case.

Two general considerations should govern the follow-up of complaints—improvement of undesirable conditions, and the identification and description of the "complainers." The first is limited only by the present state of technical knowledge and skill in the field of limb prosthetics. The second has received only casual attention in the past. Further work in this area of psychology could prove to be fruitful.

CAN THE POSTFITTING ATTITUDES OF AMPUTEES TOWARD THEIR PROSTHESES BE PREDICTED ON THE BASIS OF THEIR PREFITTING EXPECTATIONS?

As we have seen, the attitudes held by the amputees before they had participated in the program were modified by their subsequent experience with prostheses. The shift was generally toward a more realistic opinion of the results that could be obtained with prostheses. In addition to these changes, however, the attitudes of the amputees both before and after fitting showed that they placed a great deal of importance on the desirability of wearing a prosthesis. The next step, then, was to study the relationship between an amputee's attitude before fitting and his attitude afterwards. Our aim was to determine whether or not it is possible to predict an amputee's postfitting adjustment from a knowledge of his expectations before he is fitted. To this end, the question was asked: ***Are the prefitting attitudes of amputees toward prosthetic restoration related to the attitudes they hold after fitting and a period of use?*** Or, to put the question more specifically, will the amputee who approaches the fitting with a positive attitude about prostheses tend to maintain that attitude after he has worn and used an artificial arm, and, conversely, will the amputee who starts with a less positive, ambivalent, or negative attitude toward prostheses persist in that attitude after wear and use?

Appendix IIIH, used previously to determine the degree of satisfaction of amputee expectations, was now applied to test whether or not postfitting attitudes could be predicted from the corresponding prefitting attitudes.[6] Selected for this analysis were 42 amputees, none of whom had worn a prosthesis before participating in the program. They included 18 below-elbow, 18 above-elbow, and 6 shoulder-disarticulation cases ranging in age from 17 to 54 years, in education from none to postgraduate school, and in the year of amputation from 1916 to 1955. The group was, in short, highly diverse. According to their combined expectancy scores, the subjects were placed on a continuum ranging from high to low in prosthetic expectation and were then divided into three equal groups representing high, intermediate, and low prosthetic expectancy. For comparative purposes, only the upper third, representing high expectancy, and the lower third, representing low expectancy, are used in the following analyses.

Combined Expectancy Score of High Group Compared With That of Low Group

The first step was to determine whether the initial attitudes of the high-expectancy and low-expectancy groups were maintained after prosthetic experience or were modified by it.

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[6] A measurement of prosthetic expectancy was obtained by a system of scores and ratings similar to that used in the analysis of the results obtained with Appendix IIIG. Each question in Appendix IIIH had five possible answers ranging from one that expressed very positive feelings to one expressing very negative feelings. The response reflecting the most favorable attitude was given a score of 1, that reflecting the least favorable attitude a score of 5. There was thus obtained a score for each item as well as an average score for the questionnaire as a whole (combined expectancy score). Each amputee was then assigned a rating which represented the direction and intensity of his feelings about prosthetic restoration and which was therefore a measurement of his prosthetic expectancy.

Accordingly, the attitudes of the high and low groups were compared before and after fitting,[7] as indicated in Table 3.

Table 3
AVERAGE PREFITTING AND POSTFITTING EXPECTANCY SCORES OF "HIGH" AND "LOW" GROUPS

Group	Prefitting	Postfitting
Low expectancy	2.7	2.9
High expectancy	1.9	2.2

In both instances, the difference between the average combined expectancy scores of the high-expectancy group and of the low-expectancy group was found to be statistically significant ($P < 0.05$). Moreover, the mean score for each group did not change significantly after fitting ($P > 0.05$). Thus in general positive or negative attitudes within the group were maintained after fitting.

The individual items of the questionnaire were studied in an effort to determine why within each group there was only insignificant change in the combined expectancy scores from before fitting to after fitting. Was this result owing to lack of systematic differences between evaluations? Or were gains in positive feelings toward some items canceled out by loss of positive feelings toward other items?

High and Low Group Comparisons for Individual Items

Within each group an analysis was made of the way in which the responses to individual questionnaire items changed after fitting. The opinions expressed by the high-expectancy group and by the low-expectancy group about each item before and after fitting are listed in Table 4, where it may be seen that the nine items originally used to differentiate high prosthetic expectancy from low continued to differentiate the two groups, the "high's" in every instance remaining more favorably disposed than the "low's."

Inspection of the data indicates that the lack of change from prefitting to postfitting evaluations, as measured by the combined expectancy score, does not result from the cancellation of negative changes by positive ones. The average score of both the high-expectancy and the low-expectancy groups increased (became less positive) on most items. The conclusion may thus be drawn that experience with prostheses led both groups to expect less in the way of functioning (items 1 and 2), to expect less resemblance between prostheses and natural arms (item 3), and to expect artificial arms to be more uncomfortable (item 5). On the other items, the average score either decreased or remained about the same. Both groups said that the artificial hand more closely resembled the normal hand than they had expected (item

Table 4
MEAN CHOICE FOR "HIGH" AND "LOW" GROUPS, PREFITTING AND POSTFITTING, FOR EACH ITEM ON QUESTIONNAIRE

Item	Prefitting		Postfitting	
	High	Low	High	Low
1. Functioning of prosthetic arm compared with normal arm	2.1	2.8	2.4	3.1
2. Degree of functioning to be expected in artificial limbs	1.4	2.1	1.9	2.8
3. Extent to which prosthetic arm resembles natural member	1.5	3.0	2.6	3.4
4. Extent to which artificial hand resembles normal hand	2.2	3.3	2.1	3.1
5. Estimate of comfort	1.1	1.6	1.4	2.3
6. Opinion of importance of wearing an artificial limb	2.1	3.0	2.4	2.7
7. Estimate of degree of help provided by prosthesis	1.4	2.0	1.4	2.0
8. Comparison of advantages and disadvantages of wearing a prosthesis	3.7	4.3	3.6	4.1
9. Possibility of being mistaken for a nonamputee	1.6	2.4	1.6	2.6

[7] It should be remembered that expectancy scores approaching 1 indicate favorable prosthetic attitudes, those approaching 5 indicate unfavorable attitudes.

4). The "low's" apparently found (more so than the "high's") that they had not sufficiently appreciated the advantages of wearing prostheses (item 8). Of considerable interest were the group differences in response to item 6 (the importance of wearing an arm). The "high" group showed a lessening of positive opinions, and this decrease corresponded to a decline in negative attitudes among the "low's."

Certainty of Response

Throughout the questionnaire, the amputees had been asked to indicate by code the degree of certainty they felt about each of their responses. After the initial investigation, a study was made of the certainty with which any particular response had been expressed. In the code *AS* (absolutely sure), *VS* (very sure), *FS* (fairly sure), *SU* (somewhat unsure), *VU* (very unsure), *AS* was arbitarily assigned a weight of 1; *VS* a weight of 2; *FS*, 3; *SU*, 4; and *VU*, 5. Thus was obtained an average certainty score for each person in each group. The mean certainty scores for each group, prefitting and postfitting, are shown in Table 5.

Table 5
MEAN CERTAINTY SCORES, PREFITTING AND POSTFITTING, FOR "HIGH" AND "LOW" GROUPS

Group	Degree of Certainty	
	Prefitting	Postfitting
High expectancy	1.8	1.3
Low expectancy	2.5	2.2

Amputees with high expectancy express themselves as being a good deal more certain of their responses than do the low-expectancy amputees, although both are generally quite affirmative. Since in general the amputees admit to very little prosthetic knowledge, one may wonder about the basis for such certainty. After they had acquired experience with their prostheses, both groups became even more certain in their responses, as might have been expected. But the increase in certainty among the "low's" was considerably less than the increase expressed by the "high's." There would seem to be much value in further analysis of the relationship between attitude toward prostheses and certainty of response.

Relationships Between Expectancy and Other Factors Related to Amputation

In order to learn whether or not there were systematic relationships between prosthetic-expectation level and certain other factors, the "high" and the "low" groups were compared with regard to amputation type, hand dominance, marital status, age, educational level, and age at time of amputation. Analysis indicated no statistically significant differences (*9*) between the group with high expectancy and the group with low expectancy.[8] It would appear that, for this sample, the amputees who expect considerable returns from prosthetic service and those who do not expect very much are not greatly different in the factors of amputation type, handedness, marital status, age, education, and time since amputation. The suspicion that "attitudes held by amputees about prosthetic restoration before fitting are related to the attitudes they hold after fitting and a period of use" is therefore confirmed by the data. The findings also substantiate the more specific hypothesis: *The amputee who approaches the fitting with a positive attitude about prostheses will tend to maintain that attitude after he has worn and used one; the amputee who starts with a less positive, ambivalent, or negative attitude toward prostheses will persist in that attitude after wear and use.*

It must be emphasized that these findings relate to the amputees' general attitudes toward prosthetic restoration. Any particular reaction will be a function of the general prosthetic attitude and also of the specific factor involved, whether it be that of appearance, of function, or of something else.

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[8] Kolmogorov-Smirnov and Fisher Exact Probability Tests (Siegel) indicated $P > 0.05$ in all instances.

Relationships Between High and Low Expectancy and Other Attitudes of Amputees

In the course of the studies, information also was gathered describing the attitudes, experience, and expectancies of the subjects. Not all of these data were thought to be directly related to the question of what the amputees expected from prosthetic restoration. But in continuation of the study of amputee attitudes toward prosthetic service, they were examined anyway. A nonstatistical comparison, made between high-expectancy and low-expectancy groups to detect differences with respect to other reactions, uncovered the following distinctions:

1. On the whole, the group with the high expectations reported a great deal of improvement in performance. But the low-expectation group said that performance of a number of activities was impaired after prosthetic treatment. The degree of negative change reported by the "low's" was not as great as the degree of improvement reported by the "high's." Activities showing the greatest amount of change were eating, dressing, driving, and participating in sports. The "low" group expressed the most disappointment about eating, dressing, and sports activities. The "high" group reported its greatest improvements in the areas of dressing and driving.
2. The "low's" expected more difficulties than did the "high's" (18 to 12), and in the evaluations after fitting they continued to report more difficulties (19 to 14).
3. More "high's" than "low's" reported having had favorable comments made to them about the appearance of their prostheses.
4. More "low's" than "high's" admitted to negative changes in feelings since amputation.
5. Before wearing a prosthesis, four "low's" felt resentful when new acquaintances asked about the amputation; none of the "high's" expressed any negative feelings. After wear, the "high's" still did not express resentment, although three "low's" did.
6. The most outstanding difference between the "high" and "low" groups was manifest in response to the question, *If you don't consider appearance, do you think that you could get along as well without a prosthesis as with one?* Before fitting, none of the 28 subjects responded in the negative (perhaps because they were getting a free prosthesis). Three of the "high's," however, gave extremely positive responses ("The prosthesis is like a part of my body; I cannot do without it."), while the rest of the "high's" and all of the "low's" answered more temperately ("It facilitates things, increases independence."). In the postfitting evaluation, one of the "high's" said that he could do without a prosthesis, as his was not too helpful; two of the "high's" gave extremely positive replies; and the rest were more moderately positive. The "low's" presented a much more negative picture in the postfitting evaluation. Four said that they felt they could do without a prosthesis, and only one expressed himself as being oriented very positively.

The validity of the group division appears to be supported by the sample findings from the rest of the psychological data. Although we are concerned at present with establishing points of difference between the "high" and the "low" groups, it is well to add that in many other variables, such as social sensitivity and reactions to frustration, use of these measuring instruments revealed no differences.

In conclusion, then, the hypothesis was confirmed that the attitudes of nonwearers toward prosthetic restoration are related to their attitudes after they have worn prostheses. Through the use of a set of questions, it was found possible to differentiate between favorable and unfavorable attitudes. The division of the amputees on the basis of their general attitudes toward the usefulness of prostheses gave some indication of being related to other than prosthetic factors. But judging from the results, the establishment of predictive indicators of attitude toward prosthetic restoration appears to be feasible. It should be possible to develop a predictive scale which will have clinical and research utility and which at the same time can be administered and interpreted in a relatively simple way.

SUMMARY

Throughout this section a number of recurrent themes have been encountered. Chief among these has been the amputees' need for unprejudiced recognition by nonamputees. In order to gain this recognition, the amputees consistently present themselves in a manner which only partially represents their true feelings. The interpretation of the data has therefore been that the amputees utilized the questionnaires more to express their feelings about how an amputee *should* be regarded than to state how he actually *is* treated. From this point of departure the information has been handled at two levels—the first involving the assumption that the data are valid and meaningful in themselves, the second based on the premise that the responses reflect the

conscious and subconscious wishes of the subjects.

PERSONALITY DYNAMICS OF AMPUTEES

Although 90 percent of the amputees said that they were adapted to their loss, it is doubtful that so many had really achieved this result. Evidence seemed to indicate that many of the amputees were trying to maintain feelings of bodily integrity and adequacy by denying the personal and social concomitants of amputation. Any implication of abnormality was overwhelmingly rejected. Their physical defect was consistently de-emphasized, and their goals and values were those of the normal, nondisabled person.

In almost all instances, amputees portray themselves as being as able an nonamputees. While almost never admitting to being substantially inferior to nonamputees, they do acknowledge that some extra effort is necessary to keep up with them. Other evidence confirms that amputees are, in the main, correct in stressing their ability. But their consistent refusal to acknowledge limitations reflects their own self-concern. Apparently they must exaggerate to maintain a social and vocational status equal to that of nonamputees.

Considerable stress is placed upon self-sufficiency. Amputees say they resist accepting help because it is generally unnecessary. Unexpressed, but no less important, is the feeling that to accept help makes one dependent and lowers one's status.

Sensitivity about physical prowess and appearance is one of the crucial influences in the psychological functioning of the amputee. The subjects in this study readily admitted their concern about the opinions of others, but few were ready to admit any considerable amount of sensitivity. They claimed not to resent curiosity about their appearance and to expect people to look at them. Clinical experience, however, indicates that amputees are much more sensitive and hostile toward the curious person than was indicated by the data. Not infrequently such sensitivity is denied not only to others but also to themselves.

Amputees claim to be accepted by others on the same basis as anyone else, and they reject strongly the suggestion of "different" treatment. Mostly, the subjects did not feel that amputation had been a serious source of frustration. They felt they usually could do the things they wanted. When they were unable to perform because of the amputation, their usual reaction was to try all the harder.

Finally, the general tone of the amputees is to give the impression of being optimistic about their abilities, acceptance by others, and future goals.

The positive effect of the experimental treatment program on many of these variables was demonstrated. Although no radical personality changes were observed, there were consistent indications that some decrease in sensitivity and frustration resulted from the improved management procedures and from the improved prostheses. In addition, some degree of greater acceptance of loss, increased feelings of functional adequacy, and greater ease in social situations were noted.

SOCIAL AND FUNCTIONAL FACTORS IN PROSTHETIC WEAR

The prosthetic-reaction test resoundingly confirmed the data from the questionnaires. It was clear that participation in the treatment program resulted in an increase in those responses indicating greater independence and increased feelings of security. The amputees believed there was both functional and psychological advantage in the wearing of a prosthesis. They viewed prostheses as providing the wherewithal for independent functioning. Increased confidence in their functional adequacy helped them to achieve greater self-acceptance, enabled them to face their disability more realistically, and let them view the reactions of others without feeling quite so threatened. They expected nonwearers to be more shy, more easily embarrassed, and less adaptive.

ATTITUDES TOWARD PROSTHETIC WEAR, BEFORE AND AFTER FITTING

In the final phase of the investigation two questions were asked: *Are the expectations of nonprosthesis wearers fulfilled by wearing a prosthesis?* and *Can the postfitting attitudes of amputees toward their prostheses be predicted on the basis of their prefitting expectations?*

A number of avenues of approach were utilized to answer the first question. It was found that the extent of prosthetic knowledge claimed by the amputees was very small. The implications of the lack of information were discussed, with stress upon the opportunity ignorance presents for the development of unrealistic expectations (which may influence negatively future attitudes toward prostheses). Overly ambitious ideas as to the value of prostheses were modified with experience, and after being fitted most of the amputees had more realistic expectations of the advantages to be derived from prosthetic wear.

General acceptance of the appearance of the prosthetic components was clear. There was little change in opinion regarding the extent to which prosthetic arms and hands resembled normal members. Three important constituents to the final judgment of amputee appearance were identified—the static factor of the cosmetic value of the prosthesis irrespective of function, the dynamic factor of natural appearance in use, and the situational factor of the intensity of the contact.

Preconceptions regarding comfort did not change markedly with experience. Although comfort appears to be no important problem for three fourths of the amputees, the remaining one fourth found their prostheses to be uncomfortable.

The amputees retained favorable attitudes toward the prostheses after a period of wear. Prostheses were considered to be generally helpful and very important to the amputees, the advantages far outweighing the disadvantages.

With the exception of "learning to operate," most of the difficulties anticipated in wearing an arm actually developed. In addition, other problems evolved, such as mechanical failure, stump pain, and excessive heat. A number of hypothetical personality types were described to help identify complaints based upon emotional factors as contrasted with those directly related to prosthetic or medical problems.

The second question was directed toward the idea that attitudes held before prosthetic fitting may influence the valuation of prosthetic usefulness regardless of experience. Tested and confirmed was the hypothesis that attitudes held by amputees about prosthetic restoration before fitting are related to the attitudes held after fitting and a period of use. Amputees holding favorable attitudes before using prostheses tended to maintain those attitudes after wear and use; subjects negatively disposed continued to be less favorably inclined.

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Studies of the Upper-Extremity Amputee

VIII. Research Implications

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IT WAS the purpose of the NYU Field Studies to explore the matter of the upper-extremity amputee in a broad and comprehensive way. To this end there was devised a research program consisting of three phases—survey studies, clinical studies, and evaluation studies. The first of these consisted of the single examination of each of 1630 upper-extremity amputees for the purpose of developing normative, descriptive data concerning the status of the upper-extremity-amputee population at the beginning of the research program. Through the vehicle of an organized program of prosthetic management, 769 of the 1630 amputees surveyed were provided in the clinical studies with what at the time was a new type of upper-extremity prosthesis, the purpose being to study the varieties of prostheses provided, the prescription procedures used, the preprosthetic treatment employed, the adequacy of prosthetic fabrication and fitting, the effects of training, and the results of initial and final checkouts. Finally, in the evaluation studies, the prior status, mental and physical, of 359 individuals selected from the clinical study was compared with their corresponding status after participation and treatment. The procedures used in each of these studies, and the objectives sought in the work, have all been discussed in detail in Section I of this series (ARTIFICIAL LIMBS, Spring 1958, p. 4).

While the variety, scope, and degree of completeness of the resulting data all increased as work progressed from the survey studies through the clinical studies and on to the evaluation studies, the size of the experimental sample decreased. The survey studies were limited to the normative data that could reasonably be gathered by means of a one-time interview and examination of the largest possible sample of upper-extremity amputees. The clinical studies supplemented the normative data with observational information concerning 769 amputees receiving prosthetic treatment. The evaluation studies included normative, observational, and research procedures. Only in the last series of studies did control of any research variables become possible. The major focus of the evaluation studies was, then, to obtain information on possible changes in the individual resulting from the application of new and experimental procedures in the management of the upper-extremity amputee.

The types of information sought in each of the three phases fell into one or more of five broad categories:

1. *The physical and personal characteristics of the amputees.* Included identifying data (age, height, weight, residence, marital status); educational level; vocational, avocational, and recreational pursuits; amputation etiology; amputation type; and the strength, ranges of motion, and general characteristics of the stump.

2. *The prosthetic components and fabrication techniques utilized.* Included information concerning the functional and mechanical characteristics as well as the advantages and disadvantages of each component of the artificial arm.

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3. *The treatment factors.* Included data concerning the frequency of prescription of various components, preprosthetic therapy, prosthetic training, and checkout.

4. *Amputee performance.* Concerned with testing the individual's proficiency in accomplishing the basic activities of prehension, positioning, and release of objects from grasp and with amputee reports concerning the usefulness and importance of the prosthesis in various practical activities of daily living.

5. *Psychological considerations.* Involved an assessment of amputee attitudes and personality factors as they affect reactions to prosthetic restoration as well as the social consequences of living with a disability.

While data within these five areas of interest were gathered in all three phases of the investigation, the comprehensiveness and sophistication of the measurement techniques varied from phase to phase. In view of the wide range of matters investigated, it is clear that the problems involved in their accurate measurement were considerable. Some factors (*e.g.*, mechanical characteristics of prosthetic components, results of checkout, certain personal identifying data, etc.) lent themselves rather conveniently to so-called "objective measurement," while in the light of presently available techniques other factors could be appraised only through subjective observation and rating by trained observers (*e.g.*, amputee performance, quality of prosthetic training, quality of prosthetic fabrication, etc.). Still other factors (*e.g.*, attitudes, personality factors, opinions concerning prosthetic components and treatment methods, etc.) could only be inferred from the verbal reports of the amputees themselves. As a consequence, the resulting data are of three kinds—objective measurements, observations and ratings, and amputee verbalizations. It should, however, be pointed out that no relationship necessarily exists between the significance and value of various data and their objectivity. Quite often the most objective data are the easiest to obtain but are also the least revealing. Yet certain data obviously subjective and barely capable of meeting any standards of precision provide the greatest insights and understanding.

With several relatively minor exceptions, all five subject areas have individually been the topic for separate analyses and discussions and have culminated in five corresponding articles (Sections II, III, V, VI, and VII) in this series. Section II (ARTIFICIAL LIMBS, Spring 1958, p. 57) dealt with the descriptive characteristics of the sample. Section III (ARTIFICIAL LIMBS, Spring 1958, p. 73) was concerned with the evaluation of the treatment process. Section V (page 4) reviews the specific components and fabrication techniques that go to make up a prosthesis. Section VI (page 31) describes the performance or functional capabilities of the amputee subjects, while Section VII (page 88) analyzes the psychological attributes of the amputee group.

STUDIES COMPLETED

THE SAMPLE (Section II)

The initial point of interest is that there were in the nationwide, somewhat urban sample almost as many above-elbow as there were below-elbow amputees (41 percent as compared with 51 percent). The remaining cases consisted of shoulder-disarticulation amputees (5 percent) and bilateral arm cases (3 percent). Within each of these four basic amputee types, a further detailed breakdown is presented. For example, the below-elbow cases are classified and discussed as very short, short, medium, and long, and as wrist disarticulations. A similar breakdown is offered for the above-elbow and shoulder-disarticulation groups.

It is important to emphasize that 73 percent of the participating subjects were veterans of military service who had lost limbs in World War II, a matter having a strong influence on the characteristics of the sample—on age, height, weight, educational level, and vocational status as well as on other physical characteristics.

Although certain amputees continued to pursue agricultural and mechanically oriented occupations, amputation generally resulted in a shift away from agricultural, manual, and mechanical occupations toward clerical, sales, and managerial activities, and there was in addition a very significant increase in the extent of unemployment (from 1 percent to 19 percent). Such a finding raises the question whether these shifts are caused chiefly by the physical inability to perform and compete in certain activities or primarily by socioeconomic factors.

An overwhelming majority of the subjects were found to have in their residual anatomy sufficient strength and sufficient range of motion to use an upper-extremity prosthesis. Despite this physical potential, 25 percent of the below-elbow, 39 percent of the above-elbow, and 65 percent of the shoulder-disarticulation amputees were not wearing arm prostheses at the time of the survey studies. Typically, those who did wear prostheses used Dorrance hooks, Miracle or APRL hands, and friction-type wrist units. The below-elbow prostheses typically consisted of a leather socket, rigid metal elbow hinges, and a figure-eight harness. The above-elbow and shoulder-disarticulation prostheses had in general plastic or leather sockets, manually operated or harness-controlled elbows (in about equal proportions), and chest-strap harnesses with shoulder saddles.

THE TREATMENT PROCESS (Section III)

Before the advent of the Upper-Extremity Field Studies, only some 17 percent of the group had had arms prescribed for them by a clinic team consisting of a physician, a therapist, and a prosthetist. In the NYU program, where prescriptions were written and filled in this manner routinely, all the professional groups concerned and 94 percent of the amputee subjects heartily approved of the multidisciplinary, clinical approach.

With respect to prosthetic components utilized there were several very significant shifts, such as the tendency toward the use of the APRL hook (from 12 percent to 61 percent of the sample) and toward the APRL hand (from 11 percent to 80 percent of the sample). There was also a marked increase in the use of positive-locking wrist units as compared with friction types, a strong shift toward the use of flexible hinges instead of rigid hinges for the below-elbow amputees, and an increase from 46 percent to 100 percent in the proportion of above-elbow amputees wearing harness-operated elbows. Plastic laminates were used exclusively for fabrication of the nonoperating parts of the prostheses, and the harness patterns tended to be of the figure-eight type. In point of fact, it may be said that the whole pattern of prosthetic prescription for the upper-extremity amputee was revolutionized in the course of the Upper-Extremity Field Studies.

Introduction of the checkout procedures met with considerable success. Clinic personnel considered checkout a valuable management tool, and more than 90 percent of the amputees thought it useful. Whether initial checkout or final checkout, almost 70 percent of the arms passed on the first trial. The remaining cases required two or more visits to resolve all problems, the major deficiencies uncovered being in the areas of socket fit, harnessing, and alignment of control systems.

Application of the training procedures was not nearly so successful. Some 40 percent of the group thought that the results of training could be improved by extending the instruction over a longer period and by including more and varied practice in the regimen. The finding that during the training period 54 percent of the sample needed adjustments or corrections in the prosthesis suggests the great value of supervised training—that is, of training in a situation so controlled that specific difficulties can be uncovered and resolved with a minimum of difficulty. Although the length of the training period was greater for bilateral cases than for shoulder disarticulations, greater for shoulder disarticulations than for above-elbow amputees, and so on, the time allotted for shoulder disarticulations and for above-elbow cases over that allowed below-elbow cases did not seem to be in keeping with the increase in operating difficulty known to accompany loss of the natural elbow.

All in all, the system of amputee management introduced as part of the Field Study was accorded a high degree of acceptance both by the amputees and by the professional personnel charged with their care. Perhaps the strongest recommendation for the management procedures lies in the fact that, with appropriate revisions and variations, they are now in widespread use in amputee clinics throughout the country.

THE ARMAMENTARIUM (Section V)

The data concerning the prosthetic armamentarium tend to be encyclopedic and

documentary. Each component of the upper-extremity prosthesis has been considered in terms of appearance, usefulness, ease of operation, and weight, and this information has been supplemented by data on the ranges within which the components functioned and on the magnitudes of the activating and resulting forces. The adequacy of the fabrication techniques utilized in making the upper-extremity prosthesis was also reviewed. These data provide the biomechanical basis upon which to revise a number of the checkout standards.

Lastly, the new components that go to make up the present armamentarium (terminal devices, wrist units, elbow hinges for below-elbow arms, elbow joints for above-elbow arms, control systems, and harnessing equipment) have been compared with corresponding components in the prior art. Amputee reactions toward the conventional preprogram arms have been compared with the reactions toward the new program prostheses. The amputees felt that the program prostheses are characterized by:

1. Higher, better-fitting, and better-appearing sockets.
2. More useful and easier-operating elbows.
3. Improved efficiency of force transmission reflecting better cable alignment and more stable materials.
4. Lighter, freer, and more comfortable harnessing.
5. A marked increase in terminal devices offering improved control of grasp force.

Of the 290 amputees who had an opportunity to wear both types of arms, 261 preferred the new, 25 the old, while 4 expressed no preference.

AMPUTEE PERFORMANCE (Section VI)

Section VI has been concerned with the functional value of arm prostheses, the uses to which they are put, and the skill and efficiency with which arm amputees can utilize them. From interrogation of the subjects, it became apparent that the usefulness of an arm prosthesis varied considerably from activity to activity in the five broad areas of daily living (work, home, recreation, dressing, and eating). In the numerous activities that go to make up work, recreation, and home life, prostheses tended to have wide applicability and to be most helpful to the wearer. As a matter of fact, use of the prosthesis in a variety of jobs and hobbies was much more extensive than is usually recognized, and we must therefore conclude that the functional potential of the upper-extremity amputee is also a good deal greater than commonly thought. But in the activities of dressing and eating, which for the most part involve a limited number of relatively difficult operations performed close to the body, prostheses tended to be considerably less useful. An interesting note is that, as regards the performance of any one given task, prosthetic usage tends to be on an all-or-none basis. Either the amputee uses his prosthesis every time he is confronted with a given task, or else he never uses it for that task. "Sometimes" usage is reported infrequently.

To shed further light on the comparative values of below-elbow, above-elbow, and shoulder-disarticulation prostheses, 20 selected bimanual activities, considered both by the examiners and by the amputees to be significant in terms of frequency of occurrence and of importance, were used in an attempt to determine how widely prostheses were used. In summary, the results showed that:

Over 50 percent of the below-elbow amputees always used their prostheses for 19 of the 20 tasks.

Over 50 percent of the above-elbow amputees always used their prostheses for 13 of the 20 tasks.

Over 50 percent of the shoulder-disarticulation subjects always used their prostheses for 8 of the 20 tasks.

Over 50 percent of the bilateral arm amputees always used their prostheses to accomplish 15 of 18 tasks (two tasks not applicable).

These and other data show clearly that the higher the level of amputation for which an arm prosthesis is intended the less the utility of the prosthesis. The sharp distinction between the usefulness of prostheses for below-elbow amputees and that of prostheses for above-elbow and shoulder-disarticulation amputees can be explained readily in terms of the limited function to be had from the mechanical elbow and the concomitant need for a comparatively high order of skill in order to use it properly. The difference in

apparent usefulness is clearly due to the loss of the normal anatomical elbow. This circumstance re-emphasizes the need for more practically oriented and more extended training for above-elbow and shoulder-disarticulation amputees.

While contemporary below-elbow prostheses appear to be more useful than are the corresponding prostheses for above-elbow amputations and for shoulder disarticulations, arms for the higher levels of limb loss still offer a significant measure of utility. It should also be noted that not all amputees of a given type use their prostheses to the same extent or for the same activities. Obviously, then, the prosthesis varies in value and convenience for the individual wearer, and this factor also helps to determine the amount of use made of the limb by the individual wearer.

Through a series of tests of abstract function (prehension and positioning viewed as ends in themselves) and of the performance of practical activities of daily living, a systematic, observational method of rating amputee performance was developed. Although the tests are not as precise as might be desired, an initial step in the measurement of amputee function has been taken. One direct result has been the establishment, for the upper extremity, of a set of norms which may be used as a point of comparison in evaluating amputee performance and in setting reasonable goals for prosthetic training.

The data from these tests clearly indicate that, in general, more could be accomplished with the new arms than with the old and that more skillful and more natural performance with the new prostheses was usually obtained without any increase in performance time.

The advantages of the experimental arms over the older, conventional arms were most noticeable in above-elbow and shoulder-disarticulation prostheses, less so in below-elbow prostheses. In the below-elbow case, apparently, prosthetic function is very much less dependent upon the quality or precision of arm fabrication, or on the specific components included in the prostheses, or both.

While in general the results point up the inadequacies of even our most advanced devices and techniques and thus emphasize the continued existence of much room for improvement, they also show that present-day upper-extremity prostheses are quite useful devices despite the inadequacies, especially for those types of amputees heretofore thought incapable of deriving much benefit from any prosthesis. Since we seem now to have exploited the existing concepts of upper-extremity prosthetics, there would seem to be little more to be gained by continued redesign of current prosthetic equipment. Instead, there is now a need for dramatic, if not drastic, new concepts in approaching the problem of rehabilitating the upper-extremity amputee.

AMPUTEE ATTITUDES AND REACTIONS (Section VII)

Section VII attacked the problem of prosthetic restoration from the point of view of the psychological characteristics of the amputee and tried to evaluate the subjects on the basis of nine personality variables, to explore a number of factors influencing prosthetic wear and function in social situations, and to study the amputees' attitudes toward prosthetic wear before and after fitting with a prosthesis. The predominant finding as regards the personality functioning of the amputees was that, no matter which aspect was studied, the subjects appeared to try consistently to maintain feelings of bodily integrity and adequacy by denying many of the personal, vocational, and social consequences of amputation. They consistently de-emphasized their physical difficulty, rejected notions of abnormality, and set their cosmetic and functional desires in line with those of normal people. Superimposed on this general positive tone of the amputees' statements concerning adjustment was the additional positive effect of the treatment program on many of the personality variables, as evidenced by consistent indications of some decrease in expressed feelings of sensitivity and frustration, increased feelings of functional and social adequacy, and greater acceptance of their disability.

One problem associated with this aspect of the study was that, because of the limitations of the experimental design, the data

were based entirely upon the voluntary expressions of the subjects themselves, who consistently tended to color their responses by hiding any attitudes which might be viewed as "negative." Aware of this difficulty in the measurement of the social and functional factors affecting prosthetic wear, the experimenters attempted a somewhat more indirect approach in the form of cartoons depicting a series of ambiguous, potentially sensitive, situations. The amputees were asked to respond to these situations, the expectation being that they would "project" their attitudes in a less inhibited form. Probably the major finding of this line of inquiry developed from the answers given when the amputees were requested to react to the cartoons as prosthesis wearers and then as nonwearers. The data show consistently positive attitudes toward prosthetic wear, the feeling being expressed that the prosthesis makes the amputee more effective and independent functionally, more self-reliant, more secure, more self-accepting, less shy, less easily embarrassed, and more adaptable. One may, of course, ask whether the amputees held these attitudes fundamentally or whether they were merely expounding an expected "cultural norm." On the basis of the available data it is not possible to answer the question.

In a comparison of the preprosthetic expectations of amputees with the actual degree to which these expectations were fulfilled after fitting, it was concluded that:

1. Normally, little prosthetic information is available to the new amputee, and this deficiency encourages the development of unrealistic expectations concerning prosthetic wear.
2. Anticipations which tended to be overly optimistic were in most cases modified downward (with considerable personal disappointment and regret) after the individual had an opportunity to wear a prosthesis.

The last question studied had to do with whether or not the postfitting behavior of the amputee toward his prosthesis is related to, and whether or not it can be predicted on the basis of, his prefitting attitudes, a matter that would seem to have significant practical implications. Should preprosthetic attitudes turn out to exercise a determining or controlling influence over later prosthetic acceptance, performance, and use, it would be desirable to attempt to influence early attitudes so as to obtain the best possible rehabilitation results. Investigation did indeed show that those amputees holding favorable attitudes before ever having had a prosthesis tended to maintain favorable attitudes after wear and use; those at first negatively disposed continued to react negatively after receiving a prosthesis.

Future Studies

Although the amputees in the NYU Field Study have thus far been assessed rather thoroughly in terms of five broad areas (physical and personal characteristics, prosthetic components and fabrication techniques, treatment procedures, prosthetic performance, and psychological orientation), little has yet been done toward exploring the relationships that may exist either within or between the several categories of data. As a matter of fact, the data reported and discussed here constitute a phenomenological picture of observed events and are therefore basically descriptive in nature. While data of this type are valuable in that they focus attention on significant occurrences and reveal what is taking place and what is changing during the period of observation, the reasons why the events occur, and the nature of the causal train producing them, can be learned only by more detailed and more definitive study.

The only studies of this more detailed variety which have been performed thus far are as follows:

1. A substantial segment of the findings concerning the unilateral amputees have been analyzed and presented in terms of the three basic amputee types—below-elbow, above-elbow, and shoulder-disarticulation amputees. But there is still a need for further analyses of this variety using finer categories in the amputee-type classification system (such as wrist disarticulation, long below-elbow, medium below-elbow, short below-elbow, very short below-elbow, etc.).
2. A number of attitudes toward prosthetic wear held by the amputees prior to prosthetic fitting have been studied and presented in relation to postfitting attitudes and psychological adjustment.

Whatever cross-correlations are attempted,

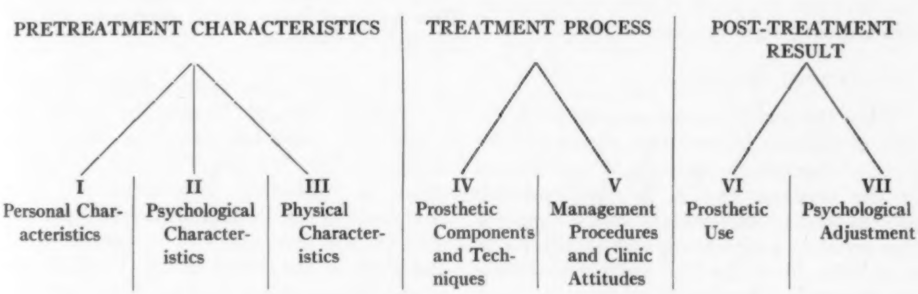
however, it must be remembered that the subject matter deals with the complex interactions between a human being, the patient, and an involved environmental process, the treatment procedure. Man is not composed of a series of discrete traits and attributes, nor does he represent the simple sum of such features Taken as a whole, the configuration is more exponential that additive. Similarly, the treatment procedures at any given level of observation may represent a series of obvious events simply measured and simply described, or they may be seen more subtly as sets of behavior of professional people—physicians, prosthetists, therapists, others—directed toward another individual, the amputee. In this light, distinctions and comparisons drawn between the patient, the treatment process, and the restorative result are unavoidably arbitrary to the extent that they tend to be abstractions from the intricate network of human behavior. Since in practice, however, analyses must be performed at some level not fully reflecting the human interactions at work, attempts at further study require some kind of conceptual framework within which to consider the data.

A CONCEPTUAL FRAMEWORK

When the mass of available data is reviewed,[2] the individual elements fall naturally into two groups—those which describe the factors contributing to the over-all result of prosthetic restoration and those which describe the result itself. The data in the first category, those dealing with the causal factors, seem in turn to constitute two separate subcategories—the individual characteristics, which the patient brings to the restoration regimen, and the treatment process, which describes the management procedures applied. Together the interaction of these two contributing factors (variables) produces the over-all result of prosthetic restoration. Thus:

Amputee Characteristics + Treatment Process → Over-All Result of Prosthetic Restoration

But each of these three broad factors consists, again in turn, of a number of more specific considerations that were the subject of investigation in the NYU Field Studies. It is therefore possible to recast the formula into somewhat more specific terms, whereupon the three factors in the original relationship are found to consist of seven different types of data. Thus:



2 Almost all of the data developed during the NYU Field Studies have been codified and punched on IBM (International Business Machines Corp.) cards, and all of the major analyses presented in this (Vol. 5, No. 2) and the preceding (Vol. 5, No. 1) issue of ARTIFICIAL LIMBS have been performed through the use of IBM electromechanical data-sorting techniques. Any future analyses may be accomplished conveniently through the same means.

Further expansion of such a breakdown leads to Table 1, which reflects in greater detail the kinds of information available. All told there are some 60 variables on which data have been collected.

The data having been thus classified, it is now necessary to find the means with which to develop whatever significant interrelationships may exist within and between the various categories. Analyses may be performed at any of the three levels of complexity, but those best undertaken first would tend to consider the segmented types of data listed in the lower portion of Table 1. Contrary to first impression, they are in reality by far the simplest to investigate. To study the earlier, more general, and apparently less complex relationships shown in the first two formulae will require the development of suitable means for consolidating individual sets of data in some meaningful way to describe the composite concepts utilized. Accordingly, analyses of the data will vary in complexity depending on whether we wish to study the relationships between discrete variables or those between increasingly composite, and therefore complex, conceptualizations. As the chosen formulation becomes clinically more meaningful, the complexity of the statistical analysis increases. Conversely, the simple selection of a pair of variables and the study of their interrelationship is easiest to effect statistically.

TWO-VARIABLE ANALYSES

When the available data are considered, the area of primary interest that comes at once to mind concerns the question of what factors in the amputee and/or in the treatment process tend to influence the over-all restoration result in a significant way, positively or negatively. Since the final level of prosthetic restoration is a composite measure made up of two different types of data, we can study various individual factors, one at a time, as they influence one segment of the rehabilitation result (use of the prosthesis by the amputee) or the other segment (the amputee's postfitting patterns of psychological adjustment). In the study of these relationships, the data concerning prosthetic performance (or those concerning amputee adjustment, one or the other) are organized and then compared systematically with data describing a variety of possible causal factors.

Since any of some 40 individual factors may influence either segment of the final result of prosthetic restoration, it becomes a matter of judgment as to which of the many possible relationships are worth checking. On the basis of previous experience, the prefitting considerations which seem to have the greatest potential significance, and which would seem to be most worth while exploring in relation to each part of the prosthetic restoration result, are as follows:

I. Personal characteristics: age, residence, education, marital status, vocation, hobbies, recreational activities.

II. Psychological characteristics: acceptance of loss, identification with the disabled, functional adequacy, independence, sensitivity, acceptance by others, sociability, frustration, optimism, security, prosthetic expectations.

III. Physical characteristics: etiology, dominant or subdominant loss, amputation level, stump strength, stump motion.

IV. Prosthetic-component characteristics: voluntary-opening *vs.* voluntary-closing terminal devices, canted *vs.* lyre-shaped fingers, range of pinch forces, friction *vs.* locking-type wrist units, step-up *vs.* nonstep-up elbow hinges, single-axis *vs.* polycentric hinges, figure-eight *vs.* shoulder-saddle harnesses, quality of prosthetic fabrication (as revealed by checkout).

V. Management procedures: extent of training, time lapse before training, extent of preprosthetic therapy, behavior and attitudes of clinic personnel (physician, therapist, prosthetist).

In this analysis, the factors included under headings I through V may be considered "predictor" variables, while the data listed under headings VI and VII may be looked upon as "criterion" information. If firm relationships can be established between the data in the first group of categories (I–V) and those in the second group (VI–VII), the former information may be used as a basis for predicting the outcomes of the prosthetic restoration process. The choice of predictor variables to be studied depends, of course, upon the segment of the prosthetic restorative result (prosthetic use or psychological adjustment) selected for study. It is, for example, quite enlightening to relate stump factors to prostehtic usage, but there would be less

Table 1

CLASSIFICATION OF TYPES OF DATA ACCUMULATED IN THE NYU FIELD STUDIES[a]

PRETREATMENT CHARACTERISTICS			TREATMENT PROCESS		POST-TREATMENT RESULT	
I Personal Characteristics	II Psychological Characteristics	III Physical Characteristics	IV Prosthetic Components and Techniques	V Management Procedures and Clinic Attitudes	VI Prosthetic Use	VII Psychological Adjustment
Age Education Residence Marital status Vocation Hobbies Recreational activities	Acceptance of loss Identification with disabled Functional adequacy Independence Sensitivity Acceptance by others Sociability Frustration Optimism Security Prosthetic expectations	Weight Height Amputation level and etiology Dominant or subdominant loss Stump strength Stump motion	Terminal devices Wrists Elbows or hinges Control systems Harnesses Quality of fabrication	Extent of training Quality of training Attitudes of clinic personnel (MD, therapist, prosthetist) Preprosthetic therapy	Prehension tests Positioning tests Practical-activity tests Reported use of prosthesis in: dressing, eating, work, home, social life, selected activities of bilaterals	Acceptance of loss Identification with disabled Functional adequacy Independence Sensitivity Acceptance by others Sociability Frustration Optimism Security Prosthetic expectations Opinions of management procedures

[a] The instruments used to elicit the types of data here classified are reproduced as appendices IA through IIIH on pages 21 through 56 of the issue of ARTIFICIAL LIMBS for Spring 1958 (Vol. 5, No. 1).

reason to select stump factors when we are interested in predicting psychological adjustment. Whatever variables are ultimately selected for study, however, the basic analytic approach remains unchanged.

A second important type of two-variable analysis can very well involve a study of what relationships exist between the two aspects of the post-treatment result itself (prosthetic use *vs.* psychological adjustment). Is there, for example, any relationship between an amputee's sense of independence and the extent to which he uses his prosthesis? Is the quality of prosthetic performance related to the individual's social sensitivity? Any number of relationships of this variety could be the subject of study, and the results would contribute to the solution of one of the problems of amputee rehabilitation. Does extensive prosthetic usage of high quality imply good general adjustment, or does good adjustment give rise to efficient prosthetic use? Or is there in fact no significant relationship between these two important aspects of successful amputee rehabilitation?

A third variety of two-variable analysis stems from the fact that even within the individual areas of prosthetic usage and of amputee behavior there are important relations to be studied. How, for example, does the amputee's performance with a prosthesis relate to the importance which he attributes to a given activity? What is the relationship between the efficiency of prosthetic use as reflected by tests (actual usage) and the efficiency as reported verbally by amputees (reported usage)? In the psychological area, what is the relationship between an amputee's feelings of sensitivity and his sense of identification with the disabled? To what extent do feelings of frustration affect the amputee's sense of functional adequacy? All these are examples of significant relationships which may exist within the given segments of the prosthetic restoration result and which may very well be amenable to study.

In addition to all these possibilities, there remains a fourth type of two-variable analysis, one concerned with the relationships between the various amputee characteristics and data concerning the treatment process. Do amputees with similar occupations, hobbies, and/or recreational pursuits receive similar prosthetic prescriptions, or is the prescribed prosthesis unrelated to these matters and more dependent upon the personal attitudes of the clinic personnel? Are the variations in prescription, training, and checkout procedures based on geographic factors, age of patient, etc.? Relationships such as these are also worth exploring.

There is no question but that a considerable amount of knowledge is to be gained from the segmented type of analytic approach described. But a major limitation and a fundamental weakness is inherent in these techniques. When correlations are limited to no more than two factors at a time, the variables concerned are unavoidably isolated out of the large complex of continuously interacting forces known to exercise control over the final result of prosthetic restoration in any given case. In separating, out of the entire data, pairs of variables that may happen to interest us, we ignore the well-known clinical observation that the whole result of prosthetic rehabilitation is the consequence of a number of simultaneous, interdependent influences. In effect the other factors are treated as "constants" at any given time, an expedient admittedly not in keeping with the facts. Were the data made up of a large number of independent variables (factors independent of other inflüences in a situation), the difficulty would be less critical. But we find in fact that only comparatively few of the items are truly independent of one another.

Although this limited analytical approach will not provide the ultimate in understanding of the prosthetic restoration process, it will provide information concerning the more salient relationships existing within the data. The technique of two-variable analysis can be carried one last step by combining selected distributions of data in order to develop indices of more general factors in the prosthetic-restoration complex. Data concerning performance on prehension tests, positioning tests, practical-activity tests, and reported use of the prosthesis may, for example, be combined to provide a composite measure of amputee performance. This combination factor

may then be studied in relation to other discrete variables or other composite factors. But before one goes very far along this path he comes face to face with the desirability of attempting a "global analysis."

GLOBAL ANALYSIS

In view of the weaknesses in the two-variable approach, it would seem desirable to be able to explore the interaction of all the various factors, each with the others. That is to say, it would be helpful to be able to gauge the extent to which each factor in the prosthetic-restoration complex affects the others and to determine to what extent the total pattern of interdependence affects the final result. In any such study of interactions of variables, we are of necessity drawn to relatively sophisticated methods in statistics, such as multiple correlation, analysis of variance, and possibly factorial analysis. That analysis by these methods would be completely fruitful is by no means assured. For unless the relationships within the data are reasonably clear-cut, the statistical procedure may not be discriminating enough to bring them to light. Deficiencies in the sampling, weaknesses in the measuring instruments, and other technical shortcomings would also tend to obscure the results.

This known risk notwithstanding, such an effort is clearly worth while and will be undertaken in view of the *possibility* of approximating the significance to be afforded various considerations involved in the prosthetic-restoration potential of an individual. Success in this more ambitious approach would shed light on the relative influence that various factors, within the amputee and within the treatment process, have on the final result. Although it is well understood clinically that not all patient characteristics or all treatment methods influence the final outcome equally, no scientifically validated picture of the relative significance of the causal factors exists to date. From further studies, one might hope to learn what combinations of amputee characteristics and treatment procedures make for the best prosthetic-restoration results and, by the same token, what combinations dictate poor results. An understanding of these matters would permit reasonable predictions as to the probable success of the restorative effort, suggest modifications of the treatment process the better to fit the needs of the individual patient, and make it possible to identify and to grade "optimum" restoration results in any given case.

Conclusion

It is clear then that this presentation constitutes an overview of the information evolving from the NYU Field Studies and suggests that a considerable amount of additional data analysis will be required before the available material will have made its final contribution to the field of upper-extremity prosthetics. Many of the remaining analyses are already in process, and it is planned to publish these results as the work is completed. It must, however, be recalled that the NYU Field Study was essentially research "in breadth" and that this approach should not be expected to answer all questions relating to the upper-extremity amputee. For many of the issues needing resolution, research embracing the study of individual cases "in depth" will be required. Meantime, it is in order to express appreciation for the singular opportunity of studying such a large group of upper-extremity amputees. Because of the nature of the disability associated with arm loss, it usually is very difficult to gather large numbers of arm amputees in any one location, and it is almost impossible to be able to subject such a group to a systematic pattern of treatment. Although it would be gratifying if it could be said that the most had been made of the unusual opportunity afforded, afterthought and hindsight tell otherwise. Unfortunately the problems of research into the unknown do not cast their shadows before, and the path to discovery remains exceedingly narrow. Until better methods of dealing with the complicated manifestations of the human being become available, we must be content with studies and analyses that can shed even small light on the challenging problems of prosthetic restoration.

Staff Participation

In the planning, operation, and reporting of the NYU Upper-Extremity Field Studies (1953–56), a number of members of the professional staff of the Prosthetic Devices Study fulfilled certain specific supervisory responsibilities, although they participated, on one occasion or another, in all phases of the program. Listed with their particular areas of major interest, they were:

Sidney Fishman, Project Direction
Edward R. Ford, Technical Coordination
Norman Berger, Instrument Development
Hector W. Kay, Data Collection
Edward Peizer, Data Collection
Earl A. Lewis, Data Reduction

The following additional members of the staff participated in the development of instruments, collection of research data, analysis of data, or preparation of reports:

Harold Berkowitz
Gavin Carter
Barbara Dunsky
Walter Goodman
Marshall A. Graham
Morris Kransdorf
Simon Levin
Bertram D. Litt
Theodore Marton
Sanford Sher
Adele Shuchatowitz
Jerome Siller
Sydelle Silverman
Warren P. Springer
Sidney Toabe
Pierre Ventur
Brennan C. Wood

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All of the principal charts and drawings in this and the preceding issue of Artificial Limbs are the work of George Rybczynski, free-lance artist of Washington, D. C.

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5. University of California (Los Angeles), Department of Engineering, *Manual of upper extremity prosthetics*, 2nd ed., W. R. Santschi and Marian P. Winston, eds., in press 1958.

Technical Notes from the Artificial Limb Program

This section of ARTIFICIAL LIMBS *is intended as an outlet for new developments in limb prosthetics which, though not deserving of a long feature article, nevertheless ought to be brought to the attention of the readers of this journal. Notes may vary in length from a single paragraph to several pages of manuscript, as appropriate. Illustrations also are acceptable.*

New Hip Joint for Canadian-Type Hip-Disarticulation Prosthesis

Since August 1957 (ARTIFICIAL LIMBS, Autumn 1957, p. 94), 15 Canadian-type hip-disarticulation prostheses have been made at the Orthopaedic Hospital in Copenhagen—10 for hip disarticulations and 5 for hemipelvectomies. But with the present method of construction (ARTIFICIAL LIMBS, Autumn 1957, p. 39) there appear certain undesirable gait characteristics that it would be tempting to try to overcome. Even when the prosthesis is aligned to give a narrow walking base, as described by Radcliffe (ARTIFICIAL LIMBS, Autumn 1957, p. 29), the patient has a tendency toward sidesway.

If we compare the function of the prosthesis with *The Major Determinants in Normal and Pathological Gait* as described by Saunders, Inman, and Eberhart [J. Bone & Joint Surg., **35A** (3):543 (1953)] we find that none of the six determinants (pelvic rotation, pelvic tilt, knee flexion in the stance phase, foot and knee mechanism, and lateral displacement of the pelvis) come in for consideration. But if sidesway of the body is to be avoided, at least two of the determinants (pelvic tilt and lateral displacement of the pelvis) must be accommodated.

In order to obtain these advantages, there has been designed a new hip joint giving about 5 deg. of pelvic tilt, together with lateral motion in the ankle and also lateral displacement of the pelvis. Construction (Fig. 1) is very simple. Inside a metal tube (A) is placed a ball bearing (E). Through the ball bearing passes a bolt (B), about which on each side of the ball bearing is placed a nylon bushing (C, G). Between the nylon bushings and the metal tube are placed two rubber bushings (D, E) of such degree of hardness that the amount of movement between the bolt and the metal pipe, with the ball bearing as the center, is about 5 deg. The whole is held together by the nut H.

The influence of this hip joint is apparent immediately. Sidesway is eliminated, and better balance is obtained in mid-stance. As will be seen, the distance between point C and point R is appreciably less in Figure 2 (where by virtue of the new joint and the lateral motion in the ankle the center of gravity is displaced laterally) than it is in Figure 3 (where the older hip joint and the conventional foot are used). There is the disadvantage that during the lateral displacement in mid-stance the prosthesis shortens a little, but this undesirable

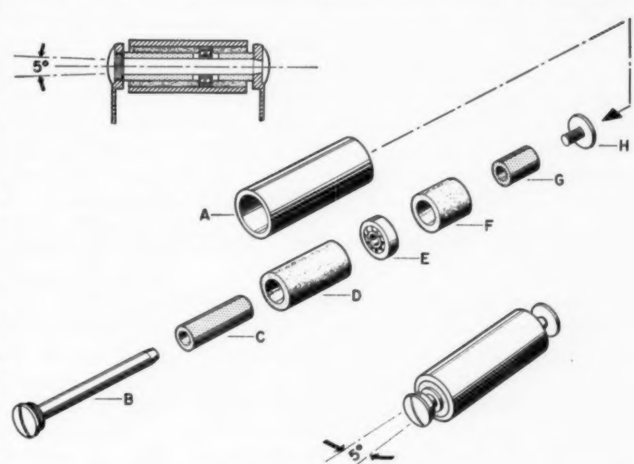


FIG. 1—New hip joint for Canadian-type hip-disarticulation prosthesis, exploded view. For description of parts, see text.

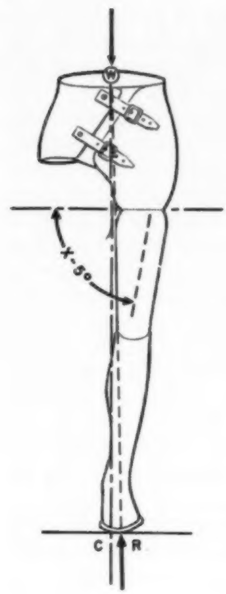


FIG. 2—Hip-disarticulation prosthesis, schematic, showing medial displacement of foot owing to 5-deg. offset in hip joint. Compare with Figure 3.

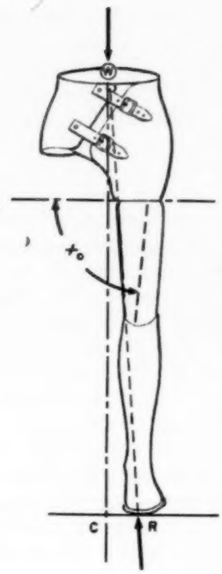


FIG. 3—Hip-disarticulation prosthesis, schematic, showing relative position of foot using conventional hip joint. Compare with Figure 2.

characteristic is outweighed by the advantages offered otherwise.

Theoretically, it is not unlikely that, besides the motion already mentioned, the new hip joint may give also a certain degree of transverse rotation. Modifications are soon to be made with a view toward obtaining improved transverse rotation.

—*Eric Lyquist*

Canadian-Type Plastic Socket for a Hemipelvectomy

Because of the lack of a really satisfactory supporting point, the fitting of the Canadian-type plastic socket for a hemipelvectomy (ARTIFICIAL LIMBS, Autumn 1957, p. 62 ff.) involves certain complications that appear difficult to overcome. But in addition to these problems is another arising from the orientation of the body surface in the area of the amputation with reference to the horizontal plane. In the hemipelvectomy, the angle between the stump surface and the horizontal is generally about 35 to 40 deg. (Fig. 1), as compared with the hip disarticulation, where the weight-bearing area remaining after amputation is almost horizontal. Lack of a good supporting point results in compression and displacement of the soft tissues vertically during weight-bearing, with a consequent "functional" shortening and "functional" lengthening of the prosthesis during the stance and swing phases respectively. Besides this, the compression causes discomfort at the groin and perineum. And finally, the slope of the amputation area results in a tendency for the body to slide down into the socket.

Only relatively few prostheses are made for hemipelvectomies, and accordingly it is difficult to find in the literature descriptions of effective methods for overcoming difficulties of this kind. Some years ago, at the Orthopaedic Hospital in Copenhagen, an attempt was made with an axillary support fixed to the socket of an old-type prosthesis, but the result was poor. Compression of the soft tissues was reduced considerably, but at the expense of uncomfortable axillary pressure and a much-reduced power of locomotion.

Another and better way has been reported by Shyh-Jong Yue and Charles R. Goldstine (*Orthopedic and Prosthetic Appliance Journal*, September 1958, p. 55; see abstract, THIS JOURNAL, p. 138). In that method, a "bridge" extending from the lower part of the socket across the mid-line to engage the remaining ischial tuberosity, or the remaining heavy muscle groups, takes over a portion of the weight-bearing. According to the authors, certain advantages are thus gained, but from a theoretical point of view certain disadvantages must also be involved. When during locomotion such a prosthesis is in the position of heel strike and the sound leg is at push-off, with hip extensors active, the bridge must evidently produce a feeling like a kick in the area about the remaining ischial tuberosity. The corresponding counterpressure would tend to rotate the prosthesis inward, and in that case the wearer would have to walk with unduly short steps.

To avoid undesirable pressure in the groin and perineum without using a bridge or an axillary support, the sloping amputation area must be accepted, which is why in the hemipelvectomy it is wrong to take the cast in the

way described by Foort (ARTIFICIAL LIMBS, Autumn 1957, p. 39) for hip disarticulations, where the patient loads the unhardened cast on a rubber pad. Use of that method causes compression and displacement of the soft tissues as in Figure 2, and pressure in the groin and perineum results. A better approach is to be had by resolving the vertical force, at least partially, into other and more tolerable force components. This can be done if a force is made to act at right angles to the chord of the arc formed by the silhouette of the amputation area. The opposite force must then act just below and just above the iliac crest on the sound side (Fig. 3).

The cast is taken with elastic plaster bandage (G. G. Kuhn, Münster, Germany). Correct use of this material gives the advantage that the female cast is absolutely exact in shape as well as in size owing to the elasticity of the bandage, which counteracts the familiar expansion that occurs during hardening of ordinary plaster bandage. As already mentioned, the patient must not load the unhardened cast. Pressure on the amputation area in the desired direction is made by the hands of the prosthetist, special care being taken to avoid pressure on the bony prominences in the area of the iliac crest (for example, by application of skived felt patches over the prominences before wrapping the plaster bandage). In order to avoid torsion in the socket, the fastening straps of the finished prosthesis must lie in a direction parallel to the acting forces, and consequently the cast should be cut along a line perpendicular to the line of the resultant force (Fig. 3). Figure 4 shows the principle applied to a prosthesis in the fitting stage.

Although the method of socket fitting here described is based on only limited experience extending over a comparatively short period of observation, it has been satisfactory in all four cases tried during a year. The results

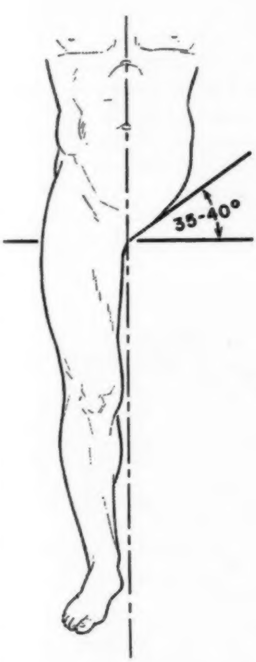


FIG. 1—Typical sloping contour of the hemipelvectomy "stump."

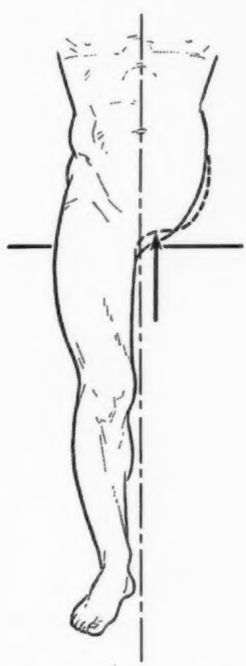


FIG. 2—Compression and displacement of soft tissues upon application of vertical force to typical hemipelvectomy "stump."

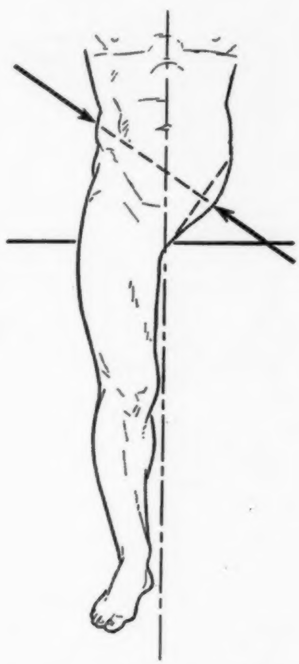


FIG. 3—Resolution of forces to get better support in the hemipelvectomy.

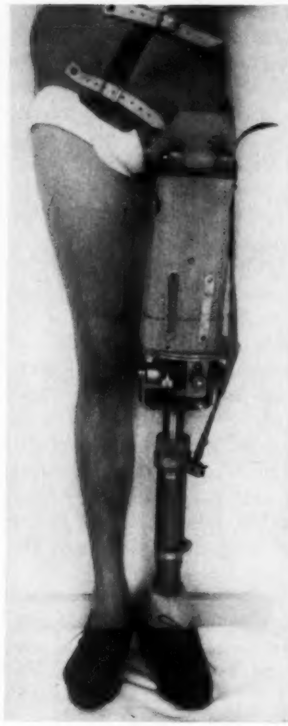


FIG. 4—Prosthesis for the hemipelvectomy, in the fitting stage.

have thus been better than expected. No uncomfortable pressure in the groin or perineum has been observed, and telescopic movements of stump in socket have been largely eliminated. The success attained to date would suggest that the method is worth trying on more cases of hemipelvectomy.

—Eric Lyquist

Danish Experience with Canadian HD

During the First International Prosthetics Course held at the Orthopaedic Hospital in Copenhagen in the summer of 1957 (ARTIFICIAL LIMBS, Autumn 1957, p. 94), a model of the Canadian-type hip-disarticulation prosthesis (ARTIFICIAL LIMBS, Autumn 1957) was demonstrated as a part of the exhibit *The Artificial Limb Program in the United States* (ARTIFICIAL LIMBS, Autumn 1957, p. 94), and a long film prepared by the Prosthetics Education Project at the University of California at Los Angeles (ARTIFICIAL LIMBS, Spring 1956, p. 43) was shown to demonstrate the technique of constructing the limb. Some of the surgeons who were students of the course observed a hemipelvectomy as performed upon a young woman by Professor Arne Bertelsen, who had recently performed two other hemipelvectomies, also on young women and all three on the left side.

Shortly after the First International Prosthetics Course, Professor Bertelsen and his colleagues decided to try to fit the three hemipelvectomies with a modification of the Canadian-type hip-disarticulation prosthesis. The instructional film was shown to the entire staff of the limbshop so that all concerned might become familiar with the principles and techniques, and a copy of the University of California report (ARTIFICIAL LIMBS, Autumn 1956, p. 66) was made available to Eric Lyquist and the other "bandagists" (the Danish equivalent of "prosthetist-orthotist"). Then a Fulbright lecturer in prosthetics, I participated in the preparation of prostheses for the three cases aforesaid and, in addition,

CANADIAN HD IN DENMARK—The fifth case. At the Orthopaedic Hospital in Copenhagen, applications of the Canadian-type hip-disarticulation prosthesis both to true disarticulations, as here, and to hemipelvectomies have been extensive since the First International Prosthetics Course in the summer of 1957. Shown with the patient are Ellen Mossin (left) and Anna Conrau, both of the Hospital staff.

for two hip-disarticulation cases, one an older woman who had previously worn an earlier type of prosthesis and the other a man who had only recently undergone amputation.

All three hemipelvectomy cases and the male hip-disarticulation case (see cut) learned to walk so rapidly and so effectively with the Canadian-type prosthesis that the staff of the Orthopaedic Hospital became deeply impressed with the concept. Indeed, Dr. Adorjan, a member of the hospital staff, suggested that the principle might well be applied to above-knee amputees, especially to fresh cases who had difficulty in learning to control the knee joint in the usual above-knee prosthesis.

In January 1958, Mr. Lyquist explained the principles and construction techniques of the Canadian-type hip-disarticulation prosthesis at a course for Scandinavian bandagists, where the idea attracted considerable attention. In June, a special course was conducted for 16 bandagists from Denmark, Norway, Sweden, and Finland. As Mr. Lyquist points out in another technical note (page 129), the Canadian-type hip-disarticulation prosthesis rapidly came into widespread use in Denmark, where he alone has already fitted a total of 15 cases.

—*Eugene F. Murphy*

Abstracts of Current Literature

This section of Artificial Limbs *is intended to summarize the current literature of limb prosthetics, especially the less accessible reports literature arising from the several research groups participating in the Artificial Limb Program. Authors are invited to submit, for review, copies of any such material, including papers published in scientific journals.*

Biochemical Design of an Improved Leg Prosthesis, C. W. Radcliffe, Series 11, Issue 33, Biomechanics Laboratory, University of California (Berkeley and San Francisco), [Report to the] Prosthetics Research Board, National Research Council, October 1957. 72 pp., illus. Free.

By far the most common, and therefore the so-called "conventional," type of prosthesis for the above-knee amputee is a comparatively elementary device, articulated in the vicinity of the corresponding normal joints, stabilized by simple mechanisms during the stance phase of walking, controlled in the swing phase by equally simple arrangements, and all based on knowledge gained more or less empirically. Despite the failure in many respects of such an artificial leg to simulate the behavior of the normal limb, the conventional above-knee prosthesis serves satisfactorily in many cases and offers a number of advantages, among them economy, durability, and ease of adjustment and maintenance.

Design of an improved artificial leg for the above-knee case would appear to require an intimate knowledge of the physiological behavior of the limbs and trunk, a detailed description of the kinematics of normal human locomotion, an adequate analysis of the biomechanics of the proposed man-machine combination, and, from the whole, the development of appropriate functional criteria suitable for engineering purposes. In pursuit of such an improved prosthesis, there are presented in this document such known details of human locomotion and such mathematical derivations as are required to define minimum functional requirements. Upon the framework of this design information there is developed an experimental above-knee leg incorporating a polycentric knee based on the four-bar linkage and controlled in the swing phase by an hydraulic damping mechanism. Of six sections, the first two are devoted to background and to the development of the necessary criteria, the next two cover the actual mechanical design on the basis of the criteria, the fifth presents the results of testing and evaluation, and the last, called "conclusion," gives the pros and cons of various possible types of control and sets forth the applications and limitations of the device described. The 17 references are used mostly to document the early and more theoretical sections.

Energy Expenditure of Normal Human Subjects During Walking, H. J. Ralston, Fed. Proc., **17**:127 (March 1958).

During studies of the energy expenditure of leg amputees walking with various assistive devices (conducted at the Biomechanics Laboratory of the University of California Medical School, San Francisco), a determination was made of the corresponding values for normal male and female subjects. Twelve normal, adult males and seven normal, adult females were studied at speeds of 1.46, 2.93, 4.39, and 5.86 km. per hr. At all speeds, average energy expenditures expressed as cal. per min. per kg. and as cal. per m. per kg. were slightly lower in males than in females. Minimal energy expenditure for both sexes occurred at 4.4 km. per hr. and was of the order of 0.7–0.8 cal. per m. per kg. The results for males are in excellent agreement with those calculated from the empirical equation given by Passmore and Durnin [Physiol. Rev., **35**:801 (1955)] but disagree with the results for males obtained by Booyens and Keatinge [J. Physiol., **138**:165 (1957)], whose values are said to appear to be too high. At all speeds, the average oxygen utilization factor, measured by oxygen uptake per minute-volume, was found to be significantly higher in males than in females. Such a result at 5.6 km. per hr. is said to be derivable from the data of Metheny *et al.* [Am. J. Physiol., **137**:318 (1942)].

This abstract, which in essence is a repetition of the corresponding abstract that appeared in the *Proceedings of the Federation of American Societies for Experimental Biology*, stems originally from a paper presented before the Eightieth Meeting of the American Physiological Society in Philadelphia April 14 through 18, 1958, and printed *in toto* in the *International Zeitschrift für angewandte Physiologie einschliesslich Arbeitsphysiologie* [**17**:277 (1958)] under the title *Energy-Speed Relation and Optimal Speed During Level Walking* (see below). The significance of the work as regards the over-all rehabilitation of amputees lies in its contribution to our basic knowledge of the relative energy requirements of normal persons and of leg amputees and of the effects that undue energy requirements contribute to some of the familiar difficulties experienced by wearers of leg prostheses. Like much other prosthetics research of a basic medical nature, the project was supported by a grant from the National Institutes of Health, United States Public Health Service, Department of Health, Education, and Welfare.

Energy-Speed Relation and Optimal Speed During Level Walking, H. J. Ralston, Int. Z. angew. Physiol. einschl. Arbeitsphysiol., **17**:277 (1958).

In the course of studies of the energy expenditure of leg amputees walking with various assistive devices, there developed at the University of California Medical School in San Francisco a need for similar data on the walking characteristics of normal subjects, the ultimate purpose being to compare corresponding values in the two cases. Accordingly, twelve normal, adult males and seven normal, adult females were subjected to measurements by a respirometer of the Max Planck type and at walking speeds of 24.4, 48.8, 73.2, and 97.6 m. per min. A few additional measurements were made at walking speeds up to 140 m. per min., and all of the results were collated with those reported by other investigators.

On the basis of the new data obtained, the principal conclusions are three in number:

1. During level walking, the energy expenditure of the human subject is a linear function of the square of the speed. The mathematical relation is: $\dot{E}_W = 29 + 0.0053\ v^2$, where $\dot{E}_W$ is the energy expenditure in cal. per min. per kg. and v is the speed in m. per min.
2. The energy expenditure per unit distance walked is derived from the above equation and is shown to take the form of a hyperbola having a minimum value of 0.78 cal. per m. per kg. at a speed of 74 m. per min.
3. A given subject adopts a "natural," or "comfortable," speed of walking that corresponds to a minimum value of the energy expenditure expressed as cal. per m. per kg.

An unresolved question regards the differences, if any, between the energy expenditure of males and of females under comparable conditions. Such differences as appeared to relate to sex (perhaps only to differences in stride length) are attributed to experimental error or else to improper judgment as to the time actually required for a walking subject to attain steady-state conditions with respect to energy expenditure. Although Booyens and Keatinge [J. Physiol., **138**:165 (1957)] made the assumption that energy expenditure would be stabilized to within 5 percent of steady conditions whenever the subject had walked 45 m. at speeds of 91 and 107 m. per min., Ralston found that, in four cases out of seven, women walking at 97.6 m. per min. did not stabilize fully within 10 min. (*i.e.*, after having walked 976 m.). It is therefore suggested that Booyens and Keatinge may have underestimated $\dot{E}_W$ in female subjects as compared with the males.

Rather profusely documented, this paper has been printed also in a condensed version in the *Proceedings of the Federation of American Societies for Experimental Biology* (see above).

The Pattern of Cutaneous Innervation of the Human Hand, Malcolm R. Miller, Henry J. Ralston III, and Michiko Kasahara, Am. J. Anat., **102**:183 (1958).

Following in the footsteps of Weddell (1954, '55), Cauna (1954, '56), Winkelmann (1956), Stilwell (1957), and others, and using for staining purposes both methylene blue perfusion and a variety of silver techniques, the present authors undertook, at the Biomechanics Laboratory of the School of Medicine at the University of California (San Francisco), to elucidate further the histological anatomy of the nervous system of the human hand. Specimens for study were obtained from human extremities amputated in surgery.

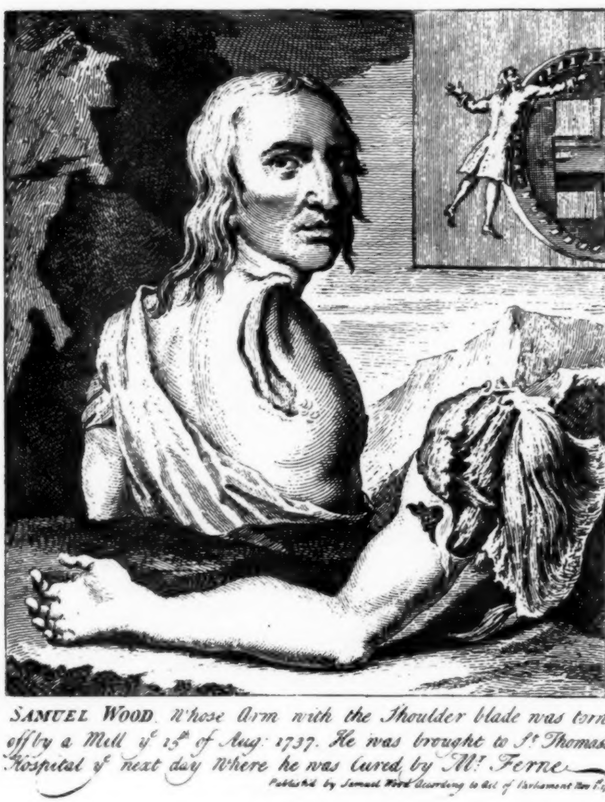
Well organized under centerheads covering background, materials and methods, and observations, the paper ends with a very credit-

able discussion of the results and a nine-point summary of specific findings. Appended as supporting evidence are 15 captioned plates in the form of photomicrographs of skin sections.

The Forequarter Amputation, H. F. Moseley, E. &. S. Livingstone Ltd., Edinburgh and London, 1957; Lippincott, Philadelphia, 1958. viii plus 79 pp.; 25 illustrations in black and white, 11 plates in full color. Livingstone, 2 g. (about $6); Lippincott, $10.

With full cognizance of his debt to countless predecessors, not to mention contemporaries, Moseley, an obvious student of his subject, sets out in this short monograph to summarize existing knowledge of the forequarter amputation—its history, its anatomical considerations, its indications and contraindications, its accepted operative procedures, and its postoperative care. In both style and content he does what appears to be an excellent job. Although it is said that the whole project was provoked by the presentation of only three cases, and although it is pointed out that eventually chemotherapeutic advances may eliminate the need for radical surgery for neoplastic disease, some real justification for the volume is implied by the inclusion of a chronological listing (said to be the first) of known forequarter amputations resulting from trauma, a factor more and more to be dealt with in mechanized life.

Two alternate surgical procedures for performing the true forequarter amputation (removal of the entire arm, including the scapula and most or all of the clavicle) are described and illustrated in detail—that from the anterior aspect (the classical method of Paul Berger, 1887) and that from the posterior aspect (Littlewood, 1922). Because of the apparent surgical interrelationships, and presumably also because of a certain confusion in terms between interscapulothoracic *amputation* (forequarter amputation) and interscapulothoracic *resection* (partial or complete removal of the scapula, often together with part or all of the clavicle and sometimes with the head of the humerus, but retaining the limb itself), there is included a short section (with an illustrated case) on the special considerations involved in removal of the shoulder girdle without removal of the limb on the same side. The special case of scapulectomy (removal of part or all of the scapula but not of the neighboring structures) is covered in another short section.



THE FOREQUARTER AMPUTATION, NONELECTIVE—Perhaps the first recorded case. Frontispiece from the 1957 volume by Moseley. *Courtesy E. & S. Livingstone Ltd., Edinburgh and London.*

A series of illustrated clinical cases, a rather extensive bibliography, and both author and subject indices complete the work. Two of the illustrations are credited to the Prosthetics Education Project at the University of California at Los Angeles.

The Program for Amputees in New York City of the New York State Division of Vocational Rehabilitation, Harry Katz, Orthop. & Pros. Appl. J., **12**(1)**:31** (March 1958).

Under the sponsorship of the New York City Office of the New York State Division of Vocational Rehabilitation, and with the cooperation of various local rehabilitation centers and of the Metropolitan Orthopedic Appliance and Limb Manufacturers Association (MOALMA), the amputee clinics of the Hospital for Special Surgery and of St. Vincent's Hospital together constitute an integrated system of management for amputee clients in greater New York City. The clinic at the Hospital for Special Surgery (founded in 1946) and that at St. Vincent's Hospital (founded in 1954) are now the principal facilities to which amputee beneficiaries are referred. Described in this article are the method of operation of the clinics, the stepwise procedure used in amputee treatment, and the system of preparatory vocational services as needed in the individual case. Viewed as a public service comparable to the public school system, the program is considered to pay its own way by virtue of the ultimate productivity of patients rehabilitated. A "supplement" provides some statistics on amputee services for fiscal year 1956, defines the goals of the work, and sets forth the requirements of applicants 14 years of age and over.

Prosthetic Devices for Children with Emphasis on Fitting Upper Extremity Amputees, Carleton Dean, Orthop. & Pros. Appl. J., **12**(2)**:91** (June 1958).

This article, by the Director of the Michigan Crippled Children Commission (Lansing), describes the work and general findings of a typical program of clinical research with juvenile amputees, outlines the kinds of prostheses that have been found suitable for children with arm amputations, and presents a statistical summation of the numbers and types of such patients seen and treated. It is thus patterned along the lines of similar documents stemming from the same source (page 146) and includes the same charts and the same data as given in the 1957 report *Upper Extremity Prosthetic Devices for Children* (ARTIFICIAL LIMBS, Autumn 1957, p. 77).

Planning Our Future, The Augusta Conference on the Future of the Prosthetic-Orthopedic Industry and Profession, Glenn E. Jackson, Orthop. & Pros. Appl. J., **12**(2)**:103** (June 1958).

In ten printed pages, the Executive Director of the Orthopedic Appliance and Limb Manufacturers Association here summarizes the topics of discussion, the conclusions reached, and the accomplishments attained at the four-day meeting of leaders of the limb and brace profession and officials of the Artificial Limb Program in Augusta, Ga., in January 1958 (ARTIFICIAL LIMBS, Spring 1958, p. 128). A practical, down-to-earth, and readily understandable presentation, this article constitutes an assessment of the present state of the prosthetics and orthotics industry and offers a peek into the future as regards economics and professionalism.

Fitting Technique Outline for Hemi-Pelvectomy Socket, John and Robert Mitchell, Orthop. & Pros. Appl. J., **12**(3)**:59** (September 1958).

Described in this article is the stepwise procedure recommended for construction of the plastic hemipelvectomy socket used by Yue and Goldstine (see below). Nine photographs illuminate the text.

Although the fabrication time is said to be very great, the results obtained are said to justify the added effort. The finished socket is said to be adequate to support patients weighing over 200 pounds.

Plastics in American Prosthetics, Carlton Fillauer, Orthop. & Pros. Appl. J., **12**(3)**:91** (September 1958).

A survey article of substantial clarity and interest, this contribution attempts to review the general status of plastics in the limb and brace industry since the first introduction (Bakelite Corp., 1942) of thermosetting, low-contact-pressure resins and the first application (Northrop Aircraft, 1943) of plastic-laminating

techniques in the field of prosthetic devices (ARTIFICIAL LIMBS, September 1955, p. 3). Described are the kinds of plastic materials now in general use in the construction of prosthetic and orthopedic appliances and some of the specific indications for this purpose or that.

An Improved Prosthesis for Hemipelvectomy, Shyh-Jong Yue and Charles R. Goldstine, Orthop. & Pros. Appl. J., **12**(3):55 (September 1958).

In an attempt (either anticipating or suggested by the Canadian-type hip-disarticulation prosthesis; see ARTIFICIAL LIMBS, Autumn 1957) to improve upon the older hemipelvectomy prosthesis using molded leather socket and wide abdominal belt, a corresponding socket of molded plastic, with shelf extending to the ischium on the sound side, was designed and fitted to ten patients, five males and five females, some youthful and some elderly. Seven of the ten were able to use their prostheses more or less successfully. Three were failures, but apparently for medical rather than prosthetic reasons.

Compare with the experience reported by Lyquist (page 130).

New Constant Friction Wrist Unit, F. A. Ritterrath and Robert E. Jones, Orthop. & Pros. Appl. J., **12**(3):97 (September 1958).

The Northrop-Sierra Model C wrist-rotation unit with "manual friction" (ARTIFICIAL LIMBS, January 1954, p. 18), introduced in 1948, provides resistance to terminal-device rotation by means of the compression of a rubber washer. But because the terminal device is threaded into the wrist unit, adjustment of terminal-device position affects the amount of resistance to further rotation, and the pitch of the threads on the terminal-device stud controls the rate of increase and decrease in rotational stability. In years of field experience, it became apparent that there was a need for a wrist unit providing constant (but adjustable) resistance to terminal-device rotation throughout the range.

In an attempt to meet this need, especially for younger children of limited strength, the prosthetics engineering group at Sierra Engineering Co. (Sierra Madre, Calif.) undertook the design of a new wrist-rotation unit in which resistance to rotation is provided by the equivalent of a brake in the form of a nylon plug bearing on the threaded surface of the terminal-device stud, the desired pressure being adjustable by virtue of a superimposed setscrew. Exceptionally durable, the nylon insert is said to last the life of a prosthesis. After an initial "break-in" period, the friction setting will remain essentially constant for the life of the unit.

Designed for use with the No. 1 child's hand (very small), the device is now being duplicated in adult sizes for testing and evaluation.

Third Annual Report, Child Amputee Prosthetics Project, a collaboration by members of the staff of CAPP, Department of Pediatrics, School of Medicine, University of California at Los Angeles, 1957. iii plus 46 pp., illus. Free.

This, the third annual report of the Child Amputee Prosthetics Project at UCLA, constitutes a record of the progress made during 1957 in the application of established principles of practice, in the development of basic data applicable to the juvenile amputee, in the pursuit of certain areas of clinical study, and in the dissemination of information to medical and paramedical personnel. Of six major chapters (background and objectives, research projects, the child-amputee population, methods of conveying information, summary of accomplishments, and statement of future plans), the second is itself a composite of reports by the respective task leaders in pediatrics, surgery, prosthetics, engineering, training, psychiatry, psychology, and social work. Chapter II thus accounts for the bulk of the material, probably in terms of significance as well as of number of pages.

Like the second report in this series (ARTIFICIAL LIMBS, Spring 1958, p. 106), the present one is also capably prepared and in a simplicity of presentation that enlists the reader's confidence more or less throughout. Statistics are limited to the graphic presentation (in Chapter III) of the characteristics of the 134 patients seen during the calendar year. The appendix, which charts available upper-extremity components for children, is much like similar tables that have been offered from time to time by the Michigan Crippled Children Commission.

By virtue of the sponsorship of CAPP, publication of the report was made possible with funds from the Children's Bureau of the U. S. Department of Health, Education, and Welfare, via the Bureau of Crippled Children Services of the Department of Public Health of the State of California.

Modern Prosthetics, A Report on the First International Prosthetics Course, Committee on Prostheses, Braces, and Technical Aids, International Society for the Welfare of Cripples, Copenhagen, Denmark, August 1–10, 1957. xii plus 97 pp. Mimeo. Available from ISWC, 701 First Ave., New York 17, New York. $0.50.

In conjunction with the Seventh World Congress of the International Society for the Welfare of Cripples in London in mid-1957 (Artificial Limbs, Autumn 1957, p. 93), the Society's Committee on Prostheses, Braces, and Technical Aids, under the chairmanship of Knud Jansen, organized and conducted at the Orthopaedic Hospital in Copenhagen the First International Prosthetics Course (Artificial Limbs, Autumn 1957, p. 94). Collected here under one cover, with a foreword by Donald V. Wilson, Secretary-General of ISWC, are a complete list of the lectures given, a tabulation of the source material used, the principal papers presented, and a list of the students, instructors, and guests. Taken as a whole, the result is a sort of "proceedings" from the ten days of instruction, discussion, and information exchange among almost 100 specialists from 21 countries. A significant feature of the dozen principal papers is that none had theretofore been published elsewhere.

A New German Method of Aligning Above-Knee Prostheses, A. P. Gruman, Orthop. & Pros. Appl. J., **12**(2):35 (June 1958).

When, in the early days of the Artificial Limb Program (1946), the Surgeon General of the U. S. Army sent to Europe his Commission on Amputations and Prostheses, it was discovered that, among other things, German prosthetists had developed the basic essentials of the suction-socket method of supporting an above-knee prosthesis and had produced a variety of mechanical aids to facilitate proper alignment of limb components by some method other than the old empirical one of "aligning by eye." While in the course of the past dozen years work in ALP has done a great deal to advance the theory and technique of above-knee alignment (University of California Adjustable Leg, see Artificial Limbs, *passim*), German prosthetists, far from being idle, have themselves worked out improved devices for above-knee alignment and fitting. Among these is a three-unit piece of apparatus contrived by the Otto Bock Orthopädische Industrie, of Duderstadt.

This article, rather profusely illustrated with photographs apparently obtained from the Bock organization, describes in some detail not only the new Bock equipment but also its method of use. A number of advantages are claimed, and it is pointed out that several American facilities are now using the Bock instruments and technique with excellent results. No direct comparison is offered between the German approach and that now most common in the United States.

Rehabilitation Medicine, Howard A. Rusk (with 36 collaborators and the editorial assistance of Eugene J. Taylor), C. V. Mosby Co., St. Louis, 1958. 572 pp., 172 illus. $12.

Especially in the decade and a half since World War II, the broad field of "rehabilitation," involving the active participation of all the medical and paramedical specialties not to mention social and vocational counseling, has come more and more itself to be recognized as a special field of practice important to a steadily increasing segment of the population. This new collaboration, produced under the supervision of Dr. Rusk, Chairman of the Department of Physical Medicine and Rehabilitation of the NYU-Bellevue Medical Center, founder of the Institute of Physical Medicine and Rehabilitation, Past-President of the International Society for the Welfare of Cripples, member of the Prosthetics Research Board, physician internationally known for his work with the handicapped, and one of the prime movers in the development of rehabilitation services here and abroad, attempts in 27 chapters to bring under one cover not only the principles of rehabilitation medicine but also the application of those principles to the care and treatment of patients suffering from all kinds of physical and mental disorders. Resulting from the combined

effort of almost two score of specialists (Rusk's colleagues and associates in the Department of Physical Medicine and Rehabilitation at NYU-Bellevue Medical Center), *Rehabilitation Medicine* appears to bear the mark of authority and to offer to the general practitioner a wealth of material that should be useful in the management of cases involving disability of one kind or another. Documentation with references to the professional literature is extensive.

Although some chapters (such as 26, *Rehabilitation Problems of Children*; 27, *Geriatric Rehabilitation*) are treated briefly and superficially (presumably for want of adequate data in the subject area concerned), others (such as 16, *Rehabilitation of the Patient with Metabolic Diseases*, 46 pages) are presented in considerable detail. Throughout, the emphasis is on malfunction of some part of the anatomy (paralysis, upset of the speech mechanism, for examples) or on disabilities associated with disordered brain function (metabolic, traumatic, or emotional). While loss of limb is recognized as a source of disability (page 19, *inter alia*), the only section on the rehabilitation of amputees is a short one incident to Chapter 17 (*Rehabilitation of the Patient with Musculoskeletal Problems*). A rather inadequate 20 pages (Chapter 9) are devoted to *Principles of Orthotics*.

Despite minor deficiencies in content such as noted here, *Rehabilitation Medicine* is well presented in a very creditable format, and it will doubtless be of great value to many workers in broad fields. Because the general concept of rehabilitation as such is still comparatively new and hence only poorly developed except in certain quarters, any weaknesses in a pioneering work of this kind can be overlooked with a good deal of candor. The index runs to 20 pages (very good, over 2000 entries).

Theoretische Grundlagen für den Bau von Kunstbeinen, insbesondere für den Oberschenkelamputierten, 3rd revised edition, Franz Schede, Ferdinand Enke Verlag, Stuttgart, 1956. viii plus 106 pp., 71 illustrations. $5.

When, before World War I, Prof. Dr. Franz Schede set out to establish a "theoretical basis for the construction of artificial legs, especially for the above-knee amputee," he found himself in an academic vacuum. For there was available at the time, for the fitting and aligning of artificial legs, no system whatever based even remotely on the fundamental principles of lower-extremity biomechanics. Out of Schede's pioneering efforts came the first reasonably rational (if understandably faulty and incomplete in many respects) method of fitting derived from simple observation of the known laws of mechanics and anatomy. For this reason, the first and classic edition of the resulting *Theoretische Grundlagen* (1919) has been cited countless times by countless workers in limb prosthetics from Schede's early day to our own, and the methods of analysis described have until very recently constituted the avenue of approach used by almost all those concerned with the systematic improvement of the comfort and performance of the above-knee amputee. The development of the so-called "plumb-line" method of alignment itself stimulated numerous varieties of fitting tools and techniques (ARTIFICIAL LIMBS, May 1954, p. 20).

Despite the absence of any new and startling revelations of major consequence, the second (1941) edition of *Theoretische Grundlagen*, somewhat enlarged and revised, continued the reputation of the work as a major contribution to the field of limb prosthetics, so that at the beginning of the Artificial Limb Program in 1945 it was still one of the principal sources of reference for modern-day researchers entering the field for the first time. Although this, the third edition of what is essentially the same document, fails to take into account more than a few of the new findings that have grown out of research during the past decade, it is still a welcome addition to the literature of prosthetics, if on no grounds other than improved accessibility.

Of six chapters, the first, called "Introduction," deals with the general biomechanics of the lower extremity and the trunk. Chapter II is concerned with the function of standing in normals, while Chapter III describes the same function in the above-knee amputee. Chapters IV and V cover the gait of normals and of above-knee amputees, respectively. Chapter VI, newly added, discusses the Schede-Habermann foot with lateral motion about the ankle, the physiological knee based on the

four-bar linkage (cf. University of California Polycentric Knee), and a hip linkage used in knee control. There is no index, but one is scarcely needed since the presentation is in clear-cut outline form with numbered and labeled sections.

Functional Bracing of the Upper Extremities, Miles H. Anderson, edited by Raymond E. Sollars, Charles C Thomas, Springfield, Ill., 1958. xv plus 463 pp., illus. $9.50.

In the absence of any broad and systematic program of research in the problems of functional body bracing, and in the absence also of any other satisfactory "how-to-do-it" manual of currently available techniques for the bracing of disordered upper extremities, the author of this volume has here put together under hard cover and with the dignifying cloak of print what would otherwise be simply an illustrated set of teaching notes intended for guidance in classroom instruction. Comprising seven main sections, entitled, respectively, *Functional Anatomy of the Hand, Functional Assistive Hand Splints, Feeders, Special Assistive Devices, Basic Anatomy of the Arm and Shoulder, Biomechanics of Functional Hand Splints and Arm Braces*, and *Functional Arm Braces*, the work as a whole purports to describe "the rationale, principles, and techniques of upper extremity bracing to prevent deformities and restore function."

By virtue of the method of presentation (more than 1000 unnumbered illustrations accompanied by corresponding but largely independent paragraphs of description and instruction—some in the first person, some in the second, and some in the third) *Functional Bracing* is not apt to be viewed by many as "literature." But in general the coverage of the stated subject seems about as complete and straightforward as one could expect of a field still largely empirical. Intended only as a preliminary tool, and therefore admittedly deficient in many respects, this new volume is actually in use as a textbook in the courses in orthotics offered by the Prosthetics Education Project at the University of California at Los Angeles (page 156).

Because of the nature of the layout, the actual content of the book is not nearly so voluminous as might be suggested by the 400-odd pages measuring 8½ by 11 in. But such material as is included probably represents the best now available on devices and techniques for functional arm bracing. The index of no more than several hundred entries seems quite superficial.

Seminar on Rehabilitation for Asia and the Far East, Indian J. Occup. Ther., Vol. IV, No. 1 (February 1958). 57 pp., illus. 1/ ($0.15).

Some 30 pages of this particular number of the official quarterly publication of the All India Occupational Therapists' Association (mailing address: The Amerind, 15th Road, Khar, Bombay 21) are devoted to a summary of the presentations made during the *Seminar on Rehabilitation for Asia and the Far East* held at Solo, Indonesia, August 26 through September 7, 1957. A half dozen papers are followed by a statement of 18 major conclusions and a set of recommendations for improving prosthetics services in Asia. The balance of the number contains, along with some miscellany, a 5-page reprint (from *Reader's Digest*) of an article (by Albert Q. Maisel) on the career of Dr. Howard A. Rusk, a member of the Prosthetics Research Board and an honorary member of AIOTA.

Rehabilitation (Section XIX of *Excerpta Medica*), abstract journal published by Excerpta Medica Foundation, New York and Amsterdam. Vol. 1, No. 1 (July 1958). 100 pp. Annual subscription fee (twelve issues): $15.

This, the first number of *Rehabilitation*, a monthly survey journal designed to summarize the world literature in the field of rehabilitation (page 171), comprises 314 abstracts of articles in some 20 different fields of interest to rehabilitation workers. Classified and sorted according to principal subject matter (physiology, neurology, psychiatry, orthopedics, appliances, physical medicine, and so on), the abstracts are then further organized by subcategory (under "appliances," for example: prosthesiology, braces, splints, shoes, walking aids, miscellaneous). A system of cross-indexing is intended to key the present abstracts to related ones in other sections of *Excerpta Medica*.

Although judging from superficial examination the abstracts themselves appear on the

whole to be capably prepared, it is hardly possible to say just how comprehensive the coverage actually is. Strangely, the approach to the issue of ARTIFICIAL LIMBS for Spring 1957 (Vol. 4, No. 1; case-study number) gave rise (in the category *Appliances, Instruments, Materials*; subcategory *Prosthesiology*) to adequate abstracts of the editorial by Bechtol and of the article by Gottlieb *et al.* but overlooked the equally important contributions by Radcliffe and associates and by the late Sterling Bunnell. If there is any reason for such picking and choosing, it is hard to detect.

In any case, the implication is that *Rehabilitation*, like many another abstract journal, may not be nearly so all-embracing as its editors would have one believe. Since that ill-defined field called "rehabilitation" is itself of such colossal proportions, to attempt a publication under that title may be biting off more than can comfortably be chewed. Such material as there is in this first number seems useful, but in fields of research incomplete literature coverage is almost as disconcerting as no coverage at all. It would be enlightening, though much too time-consuming, to analyze the contents of one or more well-known journals with the purpose of determining just how thorough (or how haphazard) editors and abstractors have been in this case. In the absence of any such assessment, the reader must content himself with whatever is offered.

Manual of Upper Extremity Prosthetics, 2nd edition, revised and enlarged, William R. Santschi and Marian P. Winston, eds., Department of Engineering, University of California at Los Angeles, 1958. xi plus 304 pp., illus. $4.

Like its predecessor, this, the second edition of what has come to be known popularly as the "upper-extremity manual," represents a compilation, in practical form, of the results of research and clinical experience with all types of arm amputees accumulated over a number of years by the Engineering Artificial Limbs Project at UCLA, the Army Prosthetics Research Laboratory of Walter Reed Army Medical Center, the Prosthetic Devices Study of New York University, several industrial organizations, and a number of other agencies and individuals participating in the Government-sponsored Artificial Limb Program. Partly descriptive, partly in the form of instructions, it brings under one cover an authoritative summary of the present state of the art of upper-extremity prosthetics. Whereas the first edition, brought out in 1952, was put together somewhat hurriedly (and in some respects prematurely) in an attempt to satisfy an urgent need for a handbook of modern shop practice, the present volume benefits from continued research and from a greatly expanded body of knowledge gained in the conduct of a whole series of upper-extremity training courses at UCLA and at NYU. Although it is pointed out that the techniques presented are not necessarily the only ones that will lead to success, it is evident that the methods offered have survived the test of widespread application and may therefore be relied upon as the now-accepted standards in the fabrication and application of arm substitutes.

The original nine chapters in the first edition have now been expanded to a total of fourteen. Included are *Measurement* (by Craig L. Taylor), *Medical Considerations* (by Robert L. Mazet, Jr., and Hyman Jampol), *Prosthetic Prescription* (by Marvin S. Gottlieb), *Mechanical Components* (by Gerald Gwynne), *Fabrication of Below-Elbow Prostheses* (by William R. Santschi), *Fabrication of Above-Elbow Prostheses* (by William R. Santschi), *Fabrication of Shoulder Prostheses* (by Craig L. Taylor), *Plastics* (by Lester Carlyle and Fred Leonard), *Harness and Control Systems* (by Miles H. Anderson), *Below-Elbow Biceps Cineplasty* (by Craig. L. Taylor), *Prosthesis Checkout* (by William R. Santschi), *Amputee Training* (by William R. Santschi and Jeannine F. Dennis), *Materials and Equipment* (by Robert E. Jones), and *New Developments* (by Marian P. Winston). In addition to the newly added chapters, a number of the original ones, notably that on training, have been greatly enlarged, and the step-by-step fabrication procedures (Chaps. V through VII) have been much simplified by elimination of what was in the first edition an unduly cumbersome system of sequence referencing. In almost every respect—in format (better scaling of illustrations), in method of reproduction (machine composition and letterpress), in selection of paper stock and method of binding (better feel and lay), and in organization of the text (greatly simplified outline)—edition two far

surpasses the quality and usefulness of edition one.

Completing the volume are a foreword by the late Craig L. Taylor, former Director of the Engineering Artificial Limbs Project at UCLA, an introduction by F. S. Strong, Jr., Chairman of the Prosthetics Research Board of the National Academy of Sciences—National Research Council, a list of contributors including those serving as consultants, and an index comprising some 350 entries.

The Clinical Treatment of Juvenile [Upper-Extremity] Amputees, 1953–1956, Prosthetic Devices Study, Research Division, College of Engineering, New York University, Report No. 115.26C, Prepared for the New York State Department of Health, August 1958. viii plus 85 pp., illus. Free.

In an attempt to apply to the juvenile arm amputee some of the benefits now available to the corresponding adult case, an investigation was undertaken of 159 upper-extremity child amputees (90 males, 69 females) ranging in age from 10 months to 15 years and drawn from 33 clinics (some urban, some rural) located throughout the United States. Included were 104 below-elbow, 36 above-elbow, 6 shoulder-disarticulation, and 13 bilateral cases, 113 being congenital and the remaining 46 having traumatic etiology. Considering the size of the sample as well as factors of age, sex, amputation type, and geographical distribution, the subjects are viewed as constituting a reasonably good representation of the child-amputee population as a whole. In addition to a discussion of the results of treatment there is included a review of current practices in the management of the juvenile arm amputee.

As judged by an increased range of activity, greater ease in accomplishing a variety of tasks, and improvement in psychological and social adjustment, over 90 percent of the children treated were considered to be successfully fitted and trained. Less than 10 percent rejected their prostheses—some because of claimed independence of any artificial arm, some because of concern over appearance, some because of discomfort, and some because of obvious emotional disturbance and maladjustment. Children successfully treated wore their arms constantly, used them in a variety of activities, and displayed greater independence, increased confidence, and better social and school adjustment.

Described as strongly influencing acceptance or rejection of a prosthesis are the personality of the child and the attitudes and expectations of the parents. Acceptance and successful use of an artificial arm were usually accompanied by such personal characteristics as a strong desire for independence, realistic expectations, acceptance of loss, identification with non-amputees, and a sense of security. Rejection of a prosthesis was often coupled with insecurity, early development of compensatory skills, low frustration tolerance, unrealistic hopes, and excessive sensitivity. Similarly, a sincere desire upon the part of the parents for the child to be independent had a great deal to do with prosthetic acceptance and use. Unwillingness of parents to accept amputation, a sense of guilt, or uncertainty about the value of the prosthesis were frequently linked with the rejection of an arm. In some cases, weak motivation on the part of the child led to rejection despite a strong desire of the parents for prosthetic restoration. The fitting of amputee children early in life helped to avoid the need for developing compensatory skills, increased the dependence of the child on his prosthesis, and often led to acceptance and broad use. The provision of good-looking, well-fitted, and properly functioning arms helped to make the value of prosthetic fitting apparent to the child. Conversely, frequent breakdown, discomfort, and inconvenience often led to rejection, particularly in the presence of weak initial motivation. Of particular significance were the inadequacies of currently available hooks for children and the lack of an adequate functional hand.

The results obtained were the outcome of a treatment process involving three major steps—prescription, checkout, and training. Since there are at present no clear-cut indications for the sizing of children's terminal devices, wrist units, or elbows, the selection of components for the juvenile remains a matter of individual judgment. Nevertheless, there are included typical below- and above-elbow prescriptions considered suitable for the various age groups. As for checkout, the standards currently used to evaluate arms for adults were used for the children. Although as regards appearance, fit, comfort, and function chil-

dren's arms were generally above the minimum standards established for adults, the checkout procedures were frequently found to be impractical, especially with the smaller children. The procedures used for the training of children in the use of artificial arms were found to be highly variable from clinic to clinic.

Out of this work the basic recommendations are fourfold—that there be developed a more realistic means of assessing the influences of personality and environment, that an attempt be made to arrive at suitable criteria for the sizing of children's prosthetic components, that work be undertaken to evolve minimum standards of appearance, comfort, and function in children's prostheses, and that attention be given to the development of a training system intended specifically for the child amputee.

Contributions of the Physical, Biological, and Psychological Sciences in Human Disability, Renato Contini and Sidney Fishman (*conference cochairmen*), I. J. Brightman, D. H. Dabelstein, R. Drillis, W. E. Frank, W. B. Haber, G. G. Hirschberg, H. A. Imus, K. S. Landauer, D. R. Lindsay, B. D. Litt, M. Marks, H. A. Mauch, L. Meyerson, M. A. Seidenfeld, W. A. Spencer, A. Staros, S. A. Weiss, and H. K. Work, Ann. N. Y. Acad. Sci., Vol. 74, Art. 1, September 30, 1958. 160 pp., illus.

On February 10 and 11, 1958, under the sponsorship of the New York Academy of Sciences (ARTIFICIAL LIMBS, Spring 1958, p. 125), there was held in New York City a conference of some 150 specialists called to assess the interdisciplinary approach to research in rehabilitation and to summarize the variety of scientific activities that have been progressing in this field. The present document consists of the papers presented at that meeting. Classified into four parts (amputation, interdisciplinary research, neuromuscular dysfunction, and sensory dysfunction), the titles include *The Application of Engineering Technology to the Simulation of Human Motions* (9 pp.), *Reactions to Loss of Limb: Physiological and Psychological Aspects* (11 pp.), *The Body Image as Related to Phantom Sensation: A Hypothetical Conceptualization of Seemingly Isolated Findings* (5 pp.), *Comments on Biological Aspects of Amputation* (2 pp.), *The Role of the Engineer in Prosthetic Development* (3 pp.), *Problems in Interdisciplinary Coordination and Communication* (5 pp.), *Interdisciplinary Research in Rehabilitation* (5 pp.), *Methods and Sources of Stimulating Interdisciplinary Research* (5 pp.), *Problems in Supervision and Future Prospects of Interdisciplinary Research* (9 pp.), *Analysis of the Hemiplegic Gait* (19 pp.), *Psychological Adjustment Patterns of the Disabled* (8 pp.), *Objective Recording and Biomechanics of Pathological Gait* (24 pp.), *Comments on Interdisciplinary Contributions in the Care of the Neuromuscularly Disabled* (7 pp.), *Contributions of the Physical Sciences to Problems of Neuromuscular Dysfunction* (2 pp.), *Engineering Research on Problems Resulting from Sensory Loss* (9 pp.), *Psychological Aspects of Sensory Disability* (8 pp.), *Research in Sensory Disorders* (9 pp.), and *Methods and Sources of Stimulating Interdisciplinary Research* (16 pp.).

Comprising as they do representation from academic circles, from government agencies, and from private institutions, the contributors to this symposium make up a broad spectrum of the kinds of workers now engaged in rehabilitation research in the United States. Experts all in their particular fields of interest and activity, together they cover most of the broad areas now acknowledged as being involved in the care and revitalization of people suffering from various handicaps. With certain minor exceptions, documentation is refreshingly thorough. Considering the general run of technical symposia, readability and general quality of presentation are surprisingly good.

Amputation Stump Pain, Thomas J. Canty and Eugene E. Bleck, U. S. Armed Forces Med. J., May 1958, p. 635. 13 pp., illus. Reprints available from the authors at the U. S. Naval Hospital, Oakland, Calif.

Although as in most other surgical procedures the removal of part or all of a limb is associated with immediate postoperative pain, amputation of an extremity carries with it in addition the likelihood of late postoperative pain of one or both of two other kinds—continued or intermittent pain in the stump itself, and continued or intermittent phantom pain (that is, pain that appears to be seated in some part of the anatomy no longer attached to the body proper). Since because in amputation all of the several kinds of tissues are necessarily

cut across, the immediate postoperative pain is inclined to be unusually severe. But it is in most cases readily handled with large doses of narcotics during the first few postoperative days. Being more subtle and hence not as well understood, phantom pain and stump pain that arises from various causes later on are both more intractable and may in fact be so unmanageable as to be totally incapacitating. Unlike congenital "amputees," who as a rule experience neither stump pain nor phantom pain, patients suffering from disease states, such as the gangrene resulting from thromboangiitis obliterans, may have not only preoperative pain but also more than the usual degree of both immediate and late postoperative discomfort.

Among the causes of late postoperative stump pain are improper fit or alignment of the artificial limb, unsatisfactory dermatological conditions arising from the wearing of the prosthetic socket, bursitis in the stump, osteomyelitis in the bone stump, anoxia of the end of the stump, osteoma and bone spurs, and unavoidable neuromata. Tentative solutions to each of these problems, together with recommended prophylactic measures to avoid some of them, are presented.

Although almost all amputees experience phantom sensations at one time or another, disabling phantom pain is seen in only a small percentage of patients, and then often after 10 or 15 years of substantial freedom from pain. It appears that in such cases the phenomenon is usually provoked by local irritation of the stump and is therefore best treated locally. Radical treatment—such as chordotomy, sympathectomy, excision of the postcentral cerebral cortex, and even prefrontal lobotomy—usually ends in failure to eliminate the symptoms. Unfortunately chronic pain, real or phantom, commonly results in alcoholism or drug addiction.

Because phantom sensation and phantom pain are believed to be due to an abnormal excitation of the pain pathways, and because under circumstances of abnormal stimulation the pathways become "conditioned," phantom pain, once experienced, tends to become more or less constant as a result of the development of a habit pattern. Present treatment consists in finding and removing the cause of local irritation.

Age of Fitting Upper-Extremity Prostheses in Children, A Clinical Study, James A. MacDonell, J. Bone & Joint Surg., **40A**:655 (June 1958). 8 pp., illus. Reprints available from the author at the Mary Free Bed Children's Hospital and Orthopaedic Center, Grand Rapids, Mich.

In an attempt to determine systematically the earliest feasible age at which a juvenile arm amputee may be fitted satisfactorily with a functional prosthesis, twelve young patients, selected from the 152 upper-extremity amputees seen at the Mary Free Bed Children's Hospital and Orthopaedic Center between 1947 and 1956, were fitted, trained, and observed—partly on an inpatient basis, partly as outpatients, and over periods ranging from a week to more than a year. Comprising four males and eight females, the subjects differed in age on admittance from five months to four years. Nine congenital cases, three traumatics, they presented a total of 14 instances of upper-extremity involvement (either actual absence of limb segments or else anomalies best treated as amputations). Average age at time of fitting was 23.5 months.

The results are presented in tabular form. On the strength of the observations, it is concluded that:

1. Prosthetic tolerance can be obtained in children as young as five months.
2. Functional patterns involving both hands at a normal distance from the trunk is best obtained with early fitting.
3. In children under 12 months of age, a passive terminal device (mitten) seems to serve best.
4. Parental acceptance of early fitting is good.
5. Early fitting does not accelerate the development of motor skills beyond the individual's own natural level of maturation.
6. Purposeful operation of an active terminal device can seldom be expected under two years and usually is not well developed before thirty months.
7. The psychic influence of early fitting, like the "masking" of sensory function in a rudimentary extremity, cannot yet be evaluated.

A Guide for Parents of Child Amputees, John Steensma, Michigan Crippled Children Commission (Carleton Dean, M.D., *Director*), Lansing, Mich., 1958. vi plus 30 pp., illus. Free.

For parents whose young children must wear limb prostheses, this practical booklet, by a man who has himself long been a bilateral arm amputee, presents most of the seemingly

obvious but nevertheless often-overlooked details essential to the proper adjustment of the young patient to an artificial limb and to the development of the full potentials of prosthetic use. No "do-it-yourself" manual, it is intended to instruct parents in correct, day-to-day supervision of a child amputee who has already been well fitted and trained in an adequately staffed clinic. Included are the elements of care and maintenance of the prosthesis and the techniques of fostering good social adjustment in school and at play.

Administrative Phases of a Child Amputee Program, Carleton Dean, Am. J. Pub. Health, **48**:750 (June 1958). 4 pp. Reprints available from the author at the Michigan Crippled Children Commission, Lansing, Mich.

This paper, said to have been presented originally before a joint session of the sections on Maternal and Child Health and on Public Health Nursing of the American Public Health Association during its Eighty-Fifth Annual Meeting in Cleveland, November 13, 1957, is less an exposition of the stated subject than an abbreviated review of the operations of the Michigan Crippled Children Commission and of some of the broad findings that have come out of its work with juvenile amputees. Due credit is given to the accomplishments of the Artificial Limb Program coordinated by the National Research Council and by its designated agency, the Prosthetics Research Board, and the familiar concept of the clinic team is emphasized here as elsewhere. But the balance of the material is given over largely to generalizations otherwise more or less obvious. Of special significance, perhaps, is the statement that centers for the rehabilitation of child amputees, and for the management in children of deformities best treated as amputations, should be limited to no more than one per million of the population (because otherwise there would not be enough cases to maintain the interest and enthusiasm of the members of the clinic team).

Digest of Major Activities of the Artificial Limb Program

This section of Artificial Limbs *is intended to present a summary of principal news events of interest in the Artificial Limb Program during the several months preceding issue. Stories of activities in the various laboratories and associated agencies, reports of meetings, photographs, and items about individuals all are acceptable.*

Seventh Meeting, PRB

According to plan (Artificial Limbs, Spring 1958, p. 112), and pursuant to certain recommendations made during the third meeting of its Executive Committee in Detroit last January, the Prosthetics Research Board held its seventh meeting at the Army-Navy Club in Washington, D. C., April 28 for the principal purpose of receiving a preliminary report from its Ad Hoc Planning Committee, a group delegated to conduct a survey of the Artificial Limb Program—to review past accomplishments, to analyze existing organization, and to lay plans for the future conduct of the work. Present to represent the various interested participants were Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the Veterans Administration; Miss Mary E. Switzer, Director, and Mr. Donald H. Dabelstein, Assistant Director, of the Office of Vocational Rehabilitation, Department of Health, Education, and Welfare; Dr. Thomas Bradley and Mr. Louis Jordan, of the Divisions of Medical Sciences and of Engineering and Industrial Research, respectively, of the National Academy of Sciences; and Dr. Paul B. Magnuson, formerly a member of PRB and now head of the Ad Hoc Planning Committee.

In a comparatively short session, the Board approved the minutes of its sixth meeting, espoused the actions taken at the third meeting of the Executive Committee, expressed deep loss in the tragic death of Craig L. Taylor (Artificial Limbs, Spring 1958, p. 130), and approved in principle the work and preliminary report of the Ad Hoc Planning Committee, which was authorized to continue its survey.

Plans for the next meeting were undecided owing to the inability to obtain a quorum during the period of the Annual Prosthetics Conference (page 148).

Meetings of PRB Executive Committee

In the continued absence of a suitable opportunity (see above) for a meeting of the full membership of the Prosthetics Research Board, the Executive Committee, which is empowered to act for PRB subject to final review and confirmation by the whole Board, held a series of meetings extending from early summer through mid-October. These included the fourth meeting (in Detroit June 18), the fifth (in Detroit August 15), and the sixth (in Washington, D. C., October 21). The minutes of the third meeting (Artificial Limbs, Spring 1958, p. 112) having been approved by PRB at its meeting in Washington April 28 (see above), the fourth session of the Executive Committee was devoted to consideration and approval of research proposals submitted to the Veterans Administration for fiscal year 1959. At the fifth meeting August 15, approval of the minutes of the fourth meeting was followed by review of the status and activities of PRB's three standing committees (the Committee on Prosthetics Research and Development, the Committee on Child Prosthetics Problems, and the Committee on Prosthetics Education and Information), exploration of the possibilities of collaboration with the Easter Seal Research Foundation (body bracing), and approval of four new techniques as recommended by the Committee on Prosthetics Research and Development (page 148).

Of the series of meetings of the Executive Committee during the summer and autumn, perhaps the most significant was the sixth, held in Washington, D. C., October 21. Approval of the minutes of the fifth meeting preceded the recommendation that Dr. Paul B. Magnuson, a former member of the Board who had resigned voluntarily to assume leadership of the Ad Hoc Planning Committee, be reappointed as a Board member, the work of the *ad hoc* committee being now well on the way

to completion. Thereafter, consideration was given to a proposed reorganization of the Committee on Prosthetics Research and Development, which had in recent years grown to the unwieldy size of 38 members. The Chairman of PRB was duly authorized to investigate the possibility of re-establishing CPRD as a committee of not more than 7 to 11 members under the chairmanship of some person properly qualified by standing in academic circles and to consider the formation of another group, called a "Conference," to be made up of the remaining members of the existing CPRD.

DR. MAGNUSON

Finally, a summary of the accomplishments of the Ad Hoc Planning Committee was accompanied by formal cognizance of the loss incurred by the untimely death of Donald H. Dabelstein (page 170), of the Office of Vocational Rehabilitation, who had been a valued member of the *ad hoc* committee. Closing the session was a review of current fiscal matters and a brief summary of miscellaneous items.

The next meeting of the Executive Committee is scheduled to be held at the Henry Ford Hospital in Detroit during January 1959.

Annual Prosthetics Conference

In accordance with the established custom of holding an Annual Assembly in the spring of each year, all key workers in the Artificial Limb Program and all committees and subcommittees of the Prosthetics Research Board met at the National Academy of Sciences in Washington, D. C., June 11 through 14. Wednesday, Thursday, and Friday (June 11, 12, and 13) and the morning of Saturday (June 14) were given over to meetings of the several panels and subpanels, while Saturday afternoon was devoted to a general summary session of the Committee of the Whole. Well represented among those present was the Orthopedic Appliance and Limb Manufacturers Association, the acknowledged industry spokesman for the limb and brace profession in the United States. Edward W. Snygg, of the R. E. Huck Company, San Francisco, was appointed chairman of the Phase II subcommittee (prototype development) to replace Howard R. Thranhardt, of Atlanta, who had resigned because of the demands of other duties.

MR. SNYGG

In addition to its usual, systematic review of the status of all items in transition, the Committee on Prosthetics Research and Development recommended for general use a group of four items considered to have met the requirements of all developmental stages. These included the method of reinforcing and finishing wooden prostheses by means of plastic laminates (ARTIFICIAL LIMBS, Autumn 1956, p. 66; Spring 1957, p. 103; Spring 1958, pp. 95, 101), a simplified technique for the fabrication of closed-end, double-wall arm sockets (ARTIFICIAL LIMBS, Autumn 1956, p. 67), a method for the color-stabilization of polyester resins (ARTIFICIAL LIMBS, Autumn 1957, p. 71), and the so-called "Hydra-Cadence" above-knee prosthesis (an hydraulic device first introduced by John H. F. Stewart, known originally as the "Stewart-Vickers leg," and long under development; see ARTIFICIAL LIMBS, May 1954, p. 13).

At what was the second meeting of the newly activated Committee on Prosthetics Education and Information (page 149), it was announced that Northwestern University Medical School, using a grant from the Office of Vocational Rehabilitation of the Department of Health, Education, and Welfare, had established a prosthetics-education program (page 158) to parallel those already in existence at the University of California at Los Angeles and at New York University (page 156). At the meeting of the Committee on Child Prosthetics Problems, it was recommended that the participation of a number of additional child-amputee clinics be solicited and that a selected number of the chiefs of such

clinics be invited to attend a conference designed to broaden the existing program in child prosthetics (page 150).

Committee on Prosthetics Education and Information

The second meeting of the Committee on Prosthetics Education and Information of the Prosthetics Research Board was held on June 12 at the National Academy of Sciences in Washington, D. C., during the Annual Prosthetics Conference (page 148). As the beginning of a series of recommended orientation tours of participating institutions (ARTIFICIAL LIMBS, Spring 1958, p. 114), certain of the committee members had met the previous day in New York City, where they visited the Prosthetic Devices Study and the prosthetics-education facilities of New York University, the Veterans Administration Prosthetics Center, and the offices of the Research and Development Division of the VA's Prosthetic and Sensory Aids Service. Present at the meeting on June 12 were members of the Prosthetics Research Board and a number of special guests representing sponsoring agencies, the prosthetics industry, and the several prosthetics schools.

In opening the business session, Brig. Gen. F. S. Strong, Jr., Chairman of PRB, stressed the need for a positive approach designed to make the results of the Artificial Limb Program available to all who are responsible for the care and management of amputees. Thereafter, approval of the minutes of the first meeting of CPEI (ARTIFICIAL LIMBS, Spring 1958, p. 114) led to formulation of plans for the group to visit facilities in the San Francisco and Los Angeles areas early in the week of September 8 and for another formal meeting of the committee, probably on the West Coast, on or about September 11.

A review of CPEI activities included reports on current prosthetics courses at New York University and at the University of California at Los Angeles, on forthcoming courses to be given at Northwestern University, and on a proposed pilot course in below-knee prosthetics at the University of California (Berkeley). Speaking for the respective institutions were Dr. Sidney Fishman, Dr. Miles H. Anderson, Dr. Clinton L. Compere, and Prof. Charles W. Radcliffe. A report by Dr. Eugene F. Murphy on behalf of the Editorial Board of ARTIFICIAL LIMBS was followed by one by Dr. Roy M. Hoover, President of the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc. Drs. Charles O. Bechtol and Cameron B. Hall, both of the Department of Orthopedic Surgery in the School of Medicine at UCLA, summarized the results of the recent pilot course in upper-extremity bracing (page 153).

Closing the meeting was a panel discussion on the introduction of prosthetic services into areas not yet served by clinic teams. Led by Dr. Samuel S. Herman, Chief of the Division of Medical Services and Facilities of the Office of Vocational Rehabilitation, Department of Health, Education, and Welfare, and Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the Veterans Administration, the meeting concluded that more detailed study of the subject would be required.

Steering Committee, CPEI

The Alfred I. duPont Institute of The Nemours Foundation, Wilmington, Del., was host to the Steering Committee of the Committee on Prosthetics Education and Information when it met for the first time on July 9. Present, in addition to the members of the Steering Committee itself, was Dr. Harold W. Glattly, Secretary of the Committee on Prosthetics Education and Information of the Prosthetics Research Board (page 147). Purpose of the meeting was to develop a proposed program for CPEI.

In a series of decisions, the Steering Committee recognized a number of potential ways of improving prosthetics services. Among these were a program designed to convey latest information and the clinic-team concept of amputee rehabilitation to medical and paramedical personnel at the "grass-roots" level, a systematic plan for the continued education of nurses and therapists, some means for compiling information materials in a variety of media (brochures, pamphlets, manuals, films, exhibits, etc.), and, eventually, a a practical method for introducing the art and science of limb prosthetics into the curricula

of medical and paramedical schools.

DR. HOOVER

Appointed to membership on the Committee on Prosthetics Education and Information was Dr. Roy M. Hoover, Medical Director of the Woodrow Wilson Rehabilitation Center, Fishersville, Va., and President of the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc.

Conference on Child Prosthetics

Pursuant to a recommendation made last June (page 148), and with the joint sponsorship of New York University and the Bureau of Medical Rehabilitation of the New York State Department of Health, the Committee on Child Prosthetics Problems held in Grand Rapids, Mich., on August 18 and 19 a clinical conference to which were invited nine clinic chiefs representing 11 of the country's largest centers for the care of juvenile amputees. Participating, in addition to these orthopedic surgeons and in addition to the members of CCPP, were representatives of several State and Federal agencies concerned with child welfare; doctors of physical medicine; the heads of the children's projects at the Michigan Crippled Children Commission, the University of California at Los Angeles, and New York University; prosthetists specializing in work with juveniles; and spokesmen for the Prosthetics Research Board. Purpose of the meeting was to assess the current status of child prosthetics and to enlist the active cooperation of the larger clinics with a view toward expanding the Child Amputee Program (ARTIFICIAL LIMBS, Spring 1958, p. 113) so as to embrace a much larger number of cases for study and evaluation and from which to collect essential data.

In the first of four sessions (morning and afternoon of the 18th and 19th), the organization and operation of the whole program in child prosthetics was reviewed. The second session was devoted to the presentation and analysis of a group of successfully fitted amputee children. The application and relative merits of terminal devices in children, including the infant, occupied the third session. Finally, the fourth session was thrown open for roundtable discussion by all participants.

Although the universal enthusiasm of the nine visiting clinic chiefs showed promise that the goal of a greatly augmented program might well be met, it was pointed out that the requirements of research might introduce into the large service clinic certain administrative and fiscal problems for which there would be no ready solution. Clinics participating in the Child Amputee Program are required to meet certain standards and to record certain data not otherwise a part of routine clinical practice. Because of difficulties anticipated in terms both of money and of personnel, the clinic chiefs agreed to study their own local situations carefully and to meet again with CCPP during the Annual Meeting of the American Academy of Orthopaedic Surgeons in Chicago next January.

Prosthetics Research Center (NU)

The Prosthetics Research Center of Northwestern University (ARTIFICIAL LIMBS, Autumn 1957, p. 88), operating under a contract between the Northwestern University Medical School and the Veterans Administration, is now located in permanent quarters in the newly remodeled basement of the Rehabilitation Institute of Chicago (401 E. Ohio St., Chicago 11). It is thus ideally located not only for the conduct of its own clinical research but also for active participation in the amputee pro-

CONFERENCE ON CHILD PROSTHETICS—Orthopedic surgeons, prosthetists, and others concerned with the rehabilitation of the juvenile amputee meet in Grand Rapids, Mich., August 18 and 19 at the invitation of the Committee on Child Prosthetics Problems. Sponsored jointly by New York University and the Bureau of Medical Rehabilitation of the State of New York, the meeting enjoyed the participation of physicians representing more than 1000 cases under active treatment. Top, Dr. George T. Aitken, consulting orthopedic surgeon with the Michigan Crippled Children Commission, delivers a lecture on the use of the voluntary-opening terminal device in very young children. Middle, Dr. Carleton Dean, Director of MCCC, discusses some of the administrative problems encountered in a child-amputee program. Bottom, Dr. Aitken presents a number of infants and toddlers that have demonstrated the success of early prosthetic fitting.

grams of the Institute, which is designed for the examination, treatment, and training of all kinds of handicapped persons and for the prosthetic rehabilitation of amputees of all ages and with varied medical complications.

Perhaps one of the most urgent needs in prosthetics research is the precise definition of specific problems, a need which can best be filled by a clinic team. At the Rehabilitation Institute, patients are processed by a clinic team consisting of surgeons, physiatrists, therapists, a psychologist, a psychiatrist, several cooperating prosthetists from Chicago limbshops, and a prosthetics engineer and an experienced limbfitter from the Research Center. The role of PRC in this group operation is to advise on biomechanical problems, to help organize all pertinent information on prosthetic treatment, to keep a systematic written and pictorial record of this information, and to interpret the data in a manner useful in the fabrication of prostheses. Since the amputee patients handled by the clinic have vastly diverse problems and unusual medical complications, properly organized records lend invaluable criteria for the design of new devices and techniques. Thus a considerable correlation between cause and site of amputation in nontraumatic cases has already been established (Artificial Limbs, Spring 1958, p. 96), and special consideration is being given to a study of the various medical problems for the purpose of determining the most suitable prosthetic treatment for each specific kind of difficulty. While in general prosthetics research in similar projects elsewhere tends to revolve about cases of a so-called "standard" type, at PRC practical investigations are under way on prosthetics for extraordinary types of amputations, on matters relating to the special case of the geriatric amputee, and on certain components of upper- and lower-extremity prostheses not under active consideration at other institutions.

To accomplish its objectives, any research center must have access to the necessary facilities. As presently established, the Prosthetics Research Center is now amply equipped for the pursuit of its mission. The

PROSTHETICS RESEARCH CENTER—A new facility in the Midwest. Housed in the remodeled basement of the Rehabilitation Institute of Chicago, and operating under a contract between the Northwestern University School of Medicine and the Veterans Administration, PRC correlates data from Institute cases and specializes in the management of unusual or bizarre amputations or those complicated by difficult medical problems. Shown, above the entrance to RIC, is the staff of the Center. Left to right: Highy Dixon, prosthetics assistant; Jessie Duff, receptionist and secretary; Colin A. McLaurin, director of the project; Dr. Clinton L. Compere, principal investigator; Fred Hampton, prosthetist; Justin Weiskopf, machinist; and Robert Taylor, draftsman, illustrator, and photographer. Upper right is view of reception room. At middle in bottom row, Mr. Hampton works on a shoulder prosthesis. Lower right, Mr. Weiskopf operates lathe in the machine shop. *Courtesy Prosthetics Research Center, Northwestern University.*

laboratory, for example, is furnished with saw, lathe, drill press, sander, router, milling machine, oven, suction table, and other modern tools essential to the fabrication of limb substitutes. Also available is a variety of still- and motion-picture equipment needed for the maintenance of records. The combined general workroom and reception room serves well as a picture studio, and in addition are an examining room, an adequate fitting room, two storerooms, a drafting room, and an office for the director.

Staffed with persons well qualified in the field of prosthetics research, the Center has as principal investigator Dr. Clinton L. Compere, Professor of Orthopaedics at Northwestern, consultant to the VA's Orthopedic and Prosthetic Appliance Clinic Team in Chicago, and a member of PRB's Committee on Prosthetics Research and Development. Director of the project is Colin A. McLaurin, an engineer formerly with the Prosthetic Services Centre of the Canadian Department of Veterans Affairs and well known as the inventor of the Canadian-type hip-disarticulation prosthesis (ARTIFICIAL LIMBS, Autumn 1957, p. 22). Fred Hampton, a prosthetist with 10 years' experience at Sunnybrook Hospital, DVA, Toronto, is laboratory supervisor. Completing the staff are Justin Weiskopf, machinist; Hughy Dixon, prosthetics assistant; Robert Taylor, draftsman, illustrator, and photographer; and Jessie Duff, secretary and receptionist.

Among the developments under way at PRC are a single-control above-elbow arm

using a single source of power for elbow flexion, terminal-device operation, and elbow locking; a chart for repositioning below-knee joints to achieve better sitting comfort; an easily defined method for fitting hemipelvectomy and hip-disarticulation sockets; a hydrostatic method of defining stump shape, particularly below-knee; a shoulder joint with multiposition locking for shoulder disarticulations and other radical amputations of the upper extremity; and a tracing machine for recording socket shapes and exterior contours for routine fitting of above- and below-knee prostheses.

Bracing Seminar, UCLA

On April 7 there convened at the School of Medicine at the University of California at Los Angeles a group of experienced bracemakers and a number of technologists from the Artificial Limb Program, the purpose being to conduct a "pilot course" in *Functional Bracing of the Upper Extremities.* Serving as "students," the industry participants collaborated in a trial run of teaching materials proposed for a later series of courses in the same subject matter. More seminar than course of instruction, the meeting continued through April 23 with the usual lectures, demonstrations, and laboratory practice. It was the first time that an educational program in the fabrication and fitting of braces had ever been offered by a medical school.

Divided into four sections (functional hand splints, feeders, special assistive devices, and functional arm braces), the subject matter covered the pattern established in the recent volume by Dr. Miles H. Anderson (page 141), and fitting was carried out by the "students." Subsequent evaluation of the course materials on the basis of this preliminary experience led to the final design of the series of *bona fide* courses already under way for the academic

TRIAL BALLOON IN ORTHOTICS—Pictured are the students and instructors who participated in the "pilot course" in *Functional Bracing of the Upper Extremities* conducted at UCLA during the period April 7 through 23. Front row, left to right, are LeRoy W. Nattress, Roy L. Snelson, Clyde E. Peach, George B. Robinson, Lawrence Czap, and Miles H. Anderson; middle, left to right, Arnold Viner, Jack E. Conry, Jerry Leavy, Wesley Prout, W. Frank Harmon, William A. Tosberg, and Walter Stauffer; back row, left to right, John J. Bray, Fred J. Sanders, Paul B. Shipp, Bert R. Titus, Stephen Hall, Francis R. Jones, and Edward L. Thompson. With eight instructors for a dozen "students," all of whom were already experienced in the field of bracemaking, the course was more nearly a seminar, the intent being to uncover any faults in the projected teaching materials.

year 1958–59 (page 156). Further details concerning this new educational effort may be obtained from Dr. Miles H. Anderson, Director of Prosthetics Education, University of California at Los Angeles, Los Angeles 24, Calif.

NYU-OALMA Orthotics Seminar

In recent years, many orthotists have begun to suggest the possibility of research programs and university courses in the field of orthotics comparable to those that now exist in prosthetics. In an attempt partially to meet these needs and to establish the basis of a sound orthotic research and education program, New York University, which has been active for many years in prosthetics research and education, and the Orthopedic Appliance and Limb Manufacturers Association, which has been a leader in the growing tendency for trade organizations to promote educational efforts, decided to sponsor jointly a seminar on lower-extremity orthotics, the purposes being to define an agreed-upon body of knowledge incorporating the thinking and practices of leading orthotists and to formulate problems in orthotics which might be amenable to systematic research.

To this end, each member facility of OALMA was asked to nominate one or more persons who would, by virtue of experience and standing in the field, best be able to contribute to the deliberations. These nominees, accomplished orthotists from all parts of the country, convened at the NYU-Bellevue Medical Center August 11–16 to discuss a comprehensive agenda on current practices in the functional bracing of the lower extremity. Present were Milburn J. Benjamin, of the M. J. Benjamin Company, Los Angeles; John F. Buckley, of Orthopedic Services of Rhode Island, Providence; Karl W. Buschenfeldt, of Buschenfeldt Orthopedic Appliances, Stoughton, Mass; Carlton E. Fillauer, of Fillauer Surgical Supplies, Chattanooga; Alfons R. Glaubitz, of the State Hospital for Crippled Children, Elizabethtown, Pa.; Charles Goldstein, of the Institute for the Crippled and Disabled, New York City; Erich Hanicke, of P. W. Hanicke Manufacturing Co., Inc., Kansas City, Mo.; W. F. Harmon, of Atlanta Brace Shop, Atlanta; William J. McIllmurray, of the Veterans Administration Prosthetics Center, New York City; Clyde E. Peach, of the Pope Brace Division, Kankakee, Ill.; and Basil Peters, of the B. Peters Co., Philadelphia. Present also, as resource people, were Dr. Eugene F. Murphy and Anthony Staros, of the Veterans Administration, New York; Dr. R. T. Bunshah and Joseph Winter, metallurgy specialists with the College of Engineering of New York University; Dr. Rudolph Drillis, Robert Burtch, Edward R. Ford, Hector W. Kay, and Gerald Stone, of the NYU Prosthetic Devices Study; and Norman Berger, Charles Fryer, and Warren P. Springer, of the Prosthetics Education Program of New York University. Chairman of the conference was Dr. Sidney Fishman, Director of the NYU Prosthetic Devices Study and of the Prosthetics Education Program of the NYU Post-Graduate Medical School.

NYU-OALMA ORTHOTICS SEMINAR—Specialists in lower-extremity body bracing meet at NYU-Bellevue August 11–16 to assess current practices and to chart a course of research and education in modern orthotics. At far left is Dr. Sidney Fishman, Director of the Prosthetic Devices Study and of the Prosthetics Education Project at New York University.

Meeting on Monday morning, August 11, this group of people, representing the leading orthotists in the entire country as well as a number of experienced specialists in the fields of engineering, materials, biomechanics, and research and education, were welcomed by such outstanding men as Drs. Howard A. Rusk and Donald Covalt, Director and Associate Director, respectively, of the Institute of Physical Medicine and Rehabilitation; John A. McCann, President of the Orthopedic Appliance and Limb Manufacturers Association; and Glenn E. Jackson, Executive Director of OALMA. Discussion took the form of the following agenda:

Agenda

LOWER-EXTREMITY ORTHOTIC SEMINAR

August 11–16, 1958

Date	*Subject*
Monday a.m.	Greetings and Introductions
August 11	Purpose of Seminar and Plan of Approach
Monday p.m.	Lower-Extremity Orthotic Components and Materials
Tuesday a.m. and p.m.	I. Bands
August 12	a. Types
	Calf, mid-thigh, upper thigh, pelvic bands
	b. Dimensional characteristics
	c. Materials
	II. Uprights
	a. Design characteristics
	Solid, tubular
	b. Materials
	III. Shoe Attachments
	a. Types
	Stirrup, caliper, foot plate
	b. Characteristics of each design
	c. Materials
	IV. Ankle Joints
	a. Basic designs
	b. Functional characteristics
	c. Stops
	d. Materials
	V. Knee Joints
	a. Basic designs
	b. Functional characteristics
	Lock types
	c. Stops
	d. Materials
	VI. Hip Joints
	a. Basic designs
	b. Functional characteristics
	Lock types
	c. Stops
	d. Materials
Wednesday a.m. and p.m.	Alignment and Fitting Considerations
August 13	I. Criteria and Methods of Determining Joint Placement
Thursday a.m.	a. Anatomical axes of ankle, knee, and hip
August 14	b. Effects of varying joint location
	II. Placement and Alignment of Upright Bars
	a. Anatomical landmarks
	b. Length and contour
	III. Positioning of Shoe Attachments
	a. Effect of variation
	IV. Shaping and Positioning Bands, Cuffs, and Lacers

Thursday p.m. August 14 Friday a.m. August 15	Bracing as Applied to Various Lower-Extremity Disabilities I. Disorders Affecting Muscles a. Materials, components, alignment, and fitting of devices for other unilateral and bilateral spastic and flaccid conditions, with and without contractures and other complications II. Disorders Affecting Bones and Joints a. Materials, components, alignment, and fitting of devices for various deformities, fractures, dislocations, and other skeletal conditions
Friday p.m. August 15	Fabrication Techniques
Saturday a.m. August 16	Summary and Conclusion

Because the subject of lower-extremity bracing covers such an impossibly diverse set of conditions of handicap, the conferees, in an attempt to simplify matters as much as possible and to provide a workable point of departure, based the deliberations of the first three days of the conference on the assumption that the physical disabilities to be dealt with were such as to cause a loss of motor power but without accompanying contractures or deformities that might influence the skeletal alignment of the affected limb. This limitation on the discussion made it possible to explore the practices in lower-extremity orthotics that might be considered "standard" or "average," without going into the myriad possible variations that particular situations might require. The succeeding two days were devoted to some of the "special cases." Here discussion revolved around bracing practice for various forms of paralysis with accompanying spasticity, contractures, and malalignment. The over-all plan, therefore, envisioned the establishment of a foundation of standard practice, which could then be modified to meet the needs of particular bracing problems. The last day of the meeting was reserved for a more or less philosophical discussion of the need for orthotic courses, the type of curriculum that might be offered, and the requirements of students with varying levels of experience.

As a whole, the conference thus amounted to a statement of current bracing practice from leading orthotists in the United States. Consequently, the results may be expected to provide a foundation for the future establishment of research and education programs in the field.

Prosthetics Education Program

In the year 1953 (ARTIFICIAL LIMBS, January 1954, p. 30), after the better part of a decade of research and clinical observation in the problems of the limbless, there was inaugurated in the Departments of Medicine and of Engineering at the University of California at Los Angeles, and under the auspices of the then Advisory Committee on Artificial Limbs (forerunner of the Prosthetics Research Board), a series of short-term, intensive courses of instruction in the modern applications of upper-extremity prosthetics as developed in what was then already known as the Artificial Limb Program. The purpose was threefold—to test the theoretical principles and projected techniques in a broad frame of reference and thus to provide a departure for further research, to improve the supply of well-trained physicians, prosthetists, therapists, and others concerned with the rehabilitation of amputees, and, concomitantly, to encourage the formation of a great many more prosthetics clinic teams to provide a basis for follow-up and evaluation under day-to-day conditions prevailing in the field.

Conceived as an indispensable adjunct to the nationwide program of research and development in limb prosthetics, and thus supported initially by funds appropriated by the U. S. Veterans Administration, the courses shortly (by 1956) proved to be so successful in the attainment of the stated goals and to constitute such an important element in the American picture of amputee service that a comparable series was instituted at New York University as a joint venture of the College of Engineering and the Post-Graduate Medical School (ARTIFICIAL LIMBS, Spring 1956, p. 39).

PROSTHETICS EDUCATION AT UCLA—The series of courses continues. Pictured, clockwise starting at upper left, are the students and instructors in a course in *Orthopedic and Prosthetic Rehabilitation for Rehabilitation Personnel* held April 28 through May 2; those in a course in *Functional Bracing of the Upper Extremities* given May 26 through 30; those participating in a course in *Clinical Prosthetics: Upper Extremity Amputations* June 2 through 20; and those in another course in *Orthopedic and Prosthetic Rehabilitation for Rehabilitation Personnel* offered June 23 through 27. The classes shown are typical of a number of others given at the University of California at Los Angeles during the spring semester of academic year 1957–58.

PROSTHETICS EDUCATION AT NYU—Some of the instructors. Top left, Charles Fryer adjusts the "perceptoscope," an instrument used in the training of amputees. Center, Norman Berger demonstrates use of a training arm. Lower right, Warren P. Springer lectures on types of human prehension. Other two photos show worksheets used in the courses.

Because of the obvious implications of such an extended program of prosthetics education, continued financial support was assumed by the Office of Vocational Rehabilitation of the U. S. Department of Health, Education, and Welfare. Currently scheduled for opening in the autumn of 1959 is still another series of courses, to be offered by the School of Medicine of Northwestern University in Chicago (page 148). Together, the three "schools" will constitute a plan geographically convenient for the prosthetics education of qualified personnel from the East Coast, the West Coast, and the Midwest.

In the natural evolution of what is now called the Prosthetics Education Program, the subject matter, once restricted to upper-extremity prosthetics, has now grown to include the fabrication and fitting of above- and below-knee artificial legs, instruction for ancillary rehabilitation personnel (rehabilitation counselors, social workers, psychologists, and so on), and seminars on the functional bracing of the upper extremities and other related topics. A number of night classes are offered as university extension courses. From an initial enrollment (in 1953) of only a handful of students, the roster of graduates now provides a listing of several thousand persons. Now in preparation is a directory of graduates of the courses at UCLA alone. It will include almost 800 names, and a tabulation of attendance at NYU during the past two and a half years would be equally impressive. Almost from the beginning, applications for enrollment have continued, with only minor exceptions, to exceed available facilities, and it is hoped that the new courses at Northwestern will help in accommodating all interested applicants.

Following the pattern now so well accepted, UCLA continued during the spring and early summer with the remainder of its scheduled courses for the academic year 1957–58 (ARTIFICIAL LIMBS, Autumn 1957, p. 88). Included were two courses in advanced prosthetics (April 3 through 5 and May 7 through 10), one course in clinical prosthetics for upper-extremity amputations (June 2 through 20), a course in functional bracing of the upper extremities (May 26 through 30), and three courses in orthopedic and prosthetic rehabilitation for rehabilitation personnel (April 28 through May 2, May 19 through 23, and June 23 through 27). Enrollments of "medical and paramedical personnel" during the period January 1 through June 30 totaled 354. "Associated professional personnel" trained during the same period totaled 291.

Similarly, NYU completed its 1957–58 schedule (ARTIFICIAL LIMBS, Autumn 1957, p. 87). Tally for the whole year shows four courses in above-knee prosthetics, two in upper-extremity prosthetics, and three in orthotics and prosthetics for vocational counselors and related rehabilitation personnel. Prosthetists took part in three advanced seminars in above-knee prosthetics. Enrollment for the year totaled 320 (103 physicians, 88 therapists, 75 prosthetists, 54 vocational counselors).

As in previous years, both NYU and UCLA have announced schedules for the coming academic year (1958–59). Northwestern University (page 148) is expected to announce a program for the year 1959–60. Details may be had at any time by addressing an inquiry to the respective directors of prosthetics education, as follows:

DR. MILES H. ANDERSON
Director, Prosthetics Education
B4-229 Medical Center
University of California at Los Angeles
Los Angeles 24, Calif.

DR. SIDNEY FISHMAN
Director, Prosthetics Education
NYU Post-Graduate Medical School
550 First Ave.
New York 16, N. Y.

DR. J. WARREN PERRY
Director, Prosthetics Education
School of Medicine
Northwestern University
401 E. Ohio St.
Chicago 11, Ill.

Choice of the institution is purely a matter of individual preference. Although by virtue of individual differences in nomenclature there are some variations in titles of courses and some minor differences in course content, a given type of course is for all intents and purposes identical at all three universities.

While actual classroom and laboratory instruction takes up a large portion of the time available at the respective prosthetics-education projects, total activities encompass a good deal more than is patent from the yearly schedules. Preparation of teaching materials, periodic revision of manuals and textbooks, presentation of lectures to lay groups, organization of short units of instruction for use in recognized university courses, review of clinical cases in connection with certain special prosthetics problems, preparation of motion pictures and other audiovisual aids for presentation before professional meetings, and consultation with the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc. (page 166) are among the numerous duties that fall within the responsibility of staff members. The net result is a program of much greater scope and much greater effectiveness than might be expected of a comparable system of apprenticeship, and it has therefore been welcomed by almost all members of the American limb and brace profession as well as by those persons of the medical and paramedical specialties who are concerned with amputee rehabilitation services.

PRB Exhibit Program

The formal exhibit of the Prosthetics Research Board, entitled *The Artificial Limb Program in the United States*, is designed to present to those concerned the structural organization and *modus operandi* used in the Government-sponsored activities to develop new and improved prosthetic devices, to evolve better techniques of fitting and training amputees, and to disseminate new-found knowledge to the members of practicing clinic teams throughout the world. Since the first half dozen successful showings (ARTIFICIAL LIMBS, Spring 1958, p. 115), the display has continued to grow in popularity with groups of varied interests. Even during the usually slow summer months, the exhibit, tended by PRB representatives, completed prearranged

engagements in conjunction with three important technical assemblies—the 105th Annual Meeting of the Minnesota State Medical Association, in Minneapolis May 22–24; the 10th Annual Assembly of the World Health Organization, also at Minneapolis, May 26 through June 6; and the 36th Annual Session of the American Congress of Physical Medicine and Rehabilitation, in Philadelphia August 26–28. On its own initiative, the Veterans Administration presented the material at a meeting of all Directors of Professional Services and Chief Medical Officers in the VA's Boston Medical Area September 18 and 19.

On the first-mentioned occasion, in Minneapolis May 22–24, the exhibit was offered as a supplement to a presentation on limb prosthetics by a group of local prosthetists. In charge was Dr. Richard H. Jones, VA Clinic Chief in Minneapolis, assisted by Robert C. Gruman, General Manager of the Winkley Company. The second Minneapolis showing, that before the Annual Assembly of WHO, was monitored by Dr. Richard R. Owen, of the Sister Elizabeth Kenny Institute. In Philadelphia, before ACPM&R, Dr. Frederick E. Vultee (Medical College of Virginia, Richmond) and Basil Peters (B. Peters Company, Philadelphia) handled details and provided a panel of prosthetists.

The presentation by the VA was in a sense a twofold operation. The exhibit was first placed in the Conference Room of the Boston Outpatient Clinic, where it was available to professional personnel from the 25 hospitals in the Boston Medical Area, which includes New York and the New England States. In conjunction with this display, Dr. Eugene E. Record, Area Office Orthopedic Consultant and Chief of the Orthopedic and Prosthetic Appliance Clinic Team, Outpatient Clinic, Boston, together with a team from the Veterans Administration Prosthetics Center, New York City, lectured and exhibited latest research developments arising from the Artificial Limb Program. Thereafter, in recognition of the 1958 National Employ the Physically Handicapped Week (week of October 6), the entire exhibit was set up in the street-level front window of the Radio Shack Corporation (see cut). There, attended by members of the staff of the Boston Outpatient Clinic and representatives from the State of Massachusetts, it received a great deal of attention from passersby, the location being on the busiest street in Boston for both shoppers and commuters.

The schedule for the balance of 1958 includes the 52nd Annual Meeting of the Southern Medical Association, at New Orleans November 5 through 6, and the 1958 Annual Convention of the National Society for Crippled Children and Adults, Inc., at Dallas

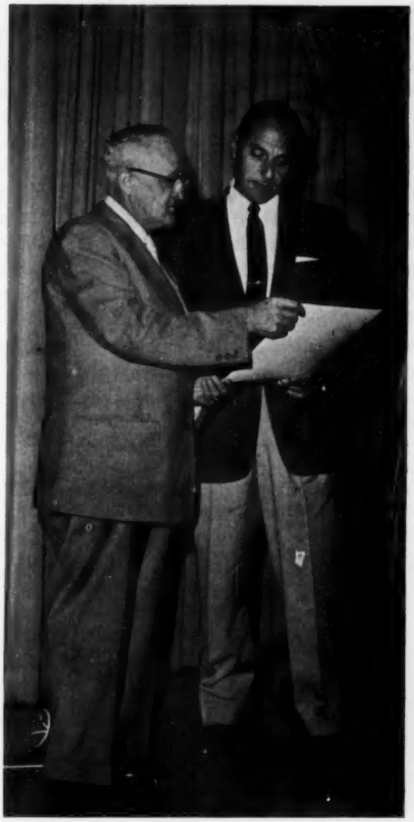
PRB EXHIBIT: HOST, RADIO SHACK—During the week of October 6, the 1958 National Employ the Physically Handicapped Week, members of the staff of the VA's Boston Outpatient Clinic and representatives of the State of Massachusetts monitored the PRB exhibit in the shopwindow of Radio Shack Corporation, nationally known mail-order house.

November 16 through 19. Requests for showings before other interested groups will be entertained by Dr. Harold W. Glattly, Secretary, Committee on Prosthetics Education and Information, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C.

OALMA National Assembly

That hopeless swamp, the fabulous Miami Beach, was the site of the 1958 National Assembly of the Limb and Brace Profession in convention at the palatial Eden Roc Hotel October 26 through 30. A combination technical session and business meeting under the sponsorship of the Orthopedic Appliance and Limb Manufacturers Association, it was, as in previous years (ARTIFICIAL LIMBS, *passim*), attended not only by many key representatives of the limbmaking and bracemaking industry but also by distinguished physicians and by outstanding research people from laboratories participating in the Artificial Limb Program. The established goals of the annual event were thus again well served by the opportunities afforded for ready interchange of scientific information from laboratory and shop, by the consequent rapport and mutual understanding required for furtherance of modern orthotics-prosthetics on a nationwide scale, and by the consolidation of past gains in the development of business principles applicable to a service enterprise so inherently characterized by limited markets and highly specialized techniques. Chairman of the Program Committee was Ralph A. Storrs, of Kankakee, Ill.

Of those active in the Artificial Limb Program, several attended by invitation and participated in the technical sessions as "resource persons" (ARTIFICIAL LIMBS, Autumn 1957, p. 100). Included were Dr. Charles O. Bechtol, Chief of the Division of Orthopedic Surgery at the University of California at Los Angeles; Col. Maurice J. Fletcher, Director of the Army Prosthetics Research Laboratory, Walter Reed Army Medical Center; and Dr. Harold W. Glattly, Secretary of the Committee on Prosthetics Education and Information of the Prosthetics Research Board (page 149). In discussion periods, accordingly, delegates had the benefit of a broad spectrum of professional experience not otherwise available.



OALMA ASSEMBLY—Charles A. Hennessy (right), Research Prosthetist with the Prosthetics Education Project at UCLA and President of the Orthopedic Appliance and Limb Manufacturers Association for the year 1956–57, receives his certificate entitling him to the privileges of membership in the OALMA Past-Presidents' Club. Doing the honors here, at Miami Beach, is OALMA's 1957–58 President, John A. McCann, of Burlington, N. J.

Other distinguished guests from research and educational circles were included among the speakers making formal presentations. Charles A. Hennessy and John J. Bray, both of the Prosthetics Education Project at UCLA, headed a session devoted to *Advances in Prosthetics*. Charles W. Radcliffe, Associate Professor of Engineering Design at the University of California (Berkeley), conducted a seminar on *Biomechanical Problems in Below-Knee*

Prosthetics. And a meeting on *Developments in Lower-Extremity Bracing and the Future* was addressed by Director Sidney Fishman and associates Basil Peters and Charles Fryer, all of the Prosthetics Education Project at New York University. Instructors for two additional seminars were Dr. Fred Leonard, Chief of the Plastics Development Branch at the Army Prosthetics Research Laboratory, who handled *New Developments in Plastics for Prosthetics*, and Anthony Staros, Chief of the Veterans Administration Prosthetics Center, New York City. Assisted by Thomas Pirrello, Jr., certified prosthetist with VAPC, Staros presented *Reinforcing Materials for Wooden Prostheses.*

Still other technical sessions included:

1. A presentation from the Pennsylvania State Hospital for Crippled Children, *Orthopedic and Orthotic Management of Certain Paralytic Foot Deformities*, by Drs. Daniel DeMeo and Jerome I. Cook, assisted by Alfons R. Glaubitz, certified orthotist.
2. An instructional course on *Accounting, Taxes, and Law for the Prosthetist-Orthotist*, by Martin Sosin, attorney and instructor at the University of California at Los Angeles.
3. A discussion and demonstration of *Functional Arm Bracing*, by George B. Robinson, of Robin-Aids Manufacturing Co., Vallejo, Calif.; Roy L. Snelson, of Rancho Los Amigos, Downey, Calif.; and Miles H. Anderson, Director of the Prosthetics Education Project at UCLA.
4. A symposium entitled *Comprehensive Management of the Older Amputee*, by Dr. Allen S. Russek, Fred J. Eschen, and William A. Tosberg, all of New York City.
5. A discussion and demonstration, *The Advantages of a Surgical Appliance Department in a Limb and Brace Facility*, by Russell E. Johnson and associates from Truform Anatomical Supports, Cincinnati.
6. A discussion of *State Rehabilitation Purchasing Procedures and the Certified Facility*, by Adrian A. Towne, Supervisor of Medical Services, Wisconsin Rehabilitation Department, and Glenn E. Jackson, Executive Director of OALMA.
7. A discussion of *Cerebral Palsy—A Medical Review and Analysis of Principal Bracing Systems*, by Dr. Harriet E. Gillette, Chief of the Division of Physical Medicine in the Health Center of the University of Florida.

ABC, LESSON IN LEADERSHIP—Pictured together with the President of the American Board for Certification are one of three newly elected Board members and two members now retiring after having served their terms of service. Left to right, Dr. Eugene E. Record, of Boston, newly chosen during the 1958 National Assembly; Dr. Roy M. Hoover, of Fishersville, Va., re-elected Board President; and retiring members Edward W. Snygg, of San Francisco, and McCarthy Hanger, Jr., of St. Louis. Not shown are two other newly elected Board members: Howard R. Thranhardt, of Atlanta, and Herbert J. Hart, of Oakland, Calif.

As a matter of special interest to physicians and other members of the rehabilitation team, the Committee on Advances in Prosthetics (page 167) presented its first report and offered three papers: *Clinic-Team Procedures* (by Dr. Eugene E. Record, Boston), *Improved Procedures in the Prescription of Appliances* (by Dr. Charles O. Bechtol, Los Angeles), and *The Role of Certification in Improved Prosthetic and Orthopedic Appliance Care* (by Dr. Roy M. Hoover, President of the American Board for Certification).

Supplementing the scientific sessions were the business meetings on October 27 and 30 and the numerous suppliers' and manufacturers' exhibits under the general supervision of Theodore W. Smith, of Kansas City, Mo., Chairman of the Exhibits Committee. In the usual annual election of officers, Karl W. Buschenfeldt, of Stoughton, Mass., former member of the American Board for Certification and formerly Vice-President of OALMA, was chosen as President for the year ending October 21, 1959. Paul E. Leimkuehler, of Cleveland, and Mr. Storrs were selected as First and Second Vice-Presidents, respectively. M. P. Cestaro, of Washington, D. C., was picked to succeed himself as Secretary-Treasurer.

As has been customary in the past, ABC met in conjunction with the OALMA Assembly, conducted an examination (page 166), held its annual business meeting, and elected officers for the coming year. Re-elected as President of ABC was Dr. Roy M. Hoover, Director of the Woodrow Wilson Rehabilitation Center at Fishersville, Va. Mr. W. Frank Harmon, of Atlanta, was chosen to serve as Vice-President while Mr. Cestaro continues as Secretary-Treasurer. Elected to fill Board vacancies created by expiring terms were Herbert J. Hart, of Oakland, Calif.; Howard R. Thranhardt, of Atlanta; and Dr. Eugene E. Record, of Boston. McCarthy Hanger, Jr., of St. Louis, and Edward W. Snygg, of San Francisco, retiring Board members, were presented with formal certificates of appreciation for their services.

At the conclusion of the meetings on Thursday, October 30, the Miami session adjourned, and some 70 OALMA members and guests enplaned for Havana for a two-day Pan-American conference at the Havana Riviera Hotel. Delegates visited rehabilitation centers in Havana, and Jerry Leavy, bilateral arm amputee and Vice-President of the Dorrance-Hosmer Companies, San Jose, Calif., gave a special demonstration of prosthetic appliances for the upper extremity. Translated into Spanish, his running commentary was later made available for general distribution throughout Cuba.

OALMA HABANERA—Appended to the 1958 National Assembly of the Limb and Brace Profession in Miami Beach was a two-day Pan-American conference in Havana. Pictured at the reception at the Havana Riviera Hotel are, left to right, Dr. Robert E. Stewart, Director of the Prosthetic and Sensory Aids Service of the U. S. Veterans Administration, Washington, D. C.; OALMA First Vice-President Paul E. Leimkuehler, of Cleveland; newly elected OALMA President (1958–59) Karl W. Buschenfeldt, of Stoughton, Mass.; Second Vice-President Ralph A. Storrs, of Kankakee, Ill.; and Lester A. Smith, editor of the *Orthopedic and Prosthetic Appliance Journal* and OALMA Assistant Executive Director.

The 1959 National Assembly of the Limb and Brace Profession will be held in the Hotel Adolphus in Dallas. Fred Quisenberry, of Los Angeles, will be Chairman of the Program Committee.

The OALMA Regions

For purposes of unified administration, and with a view toward improved professional relationships at both local and national levels, the Orthopedic Appliance and Limb Manufacturers Association, acknowledged spokesman for the limb and brace industry in the United States, divides the country into eleven geographical areas known as "Regions" (Artificial Limbs, Autumn 1957, p. 99; Spring 1958, p. 126). Each year the members of these several groups elect by written ballot a single individual member to serve as a national representative. Together with the National President, the First and Second Vice-Presidents, and the Secretary-Treasurer, the eleven "Regional Directors" thus chosen make up the Board of Directors of the national organization, which, with the aid of an Executive Director and suitable staff, is charged with the conduct of the affairs of the Association and with the implementation of the mandates of the membership.

Locally, the Regional Directors are responsible for the management of area activities. Although these vary from region to region as dictated by particular interest and inclination, they have since 1950 been manifest largely in the form of area conferences held on an annual basis and usually in the spring of the year. While some regions exhibit uncommon enthusiasm as evidenced by adoption of special area names and by monthly meetings the year around [for example, the New England Regional Council (Region I) and the Metropolitan (New York) Orthopedic Appliance and Limb Manufacturers Association (MOALMA, Region II)], the intent in all regions is the development of intragroup satisfactions and the promulgation of the educational benefits to be had from the nationwide program of research and development under way in the fields of body bracing and of limb prosthetics. Participating also on a local basis are certain independent groups (such as the Society of Prosthetists and Orthotists of Southern California) where membership tends to overlap that of OALMA itself.

Since the last announcement of regional meetings (Artificial Limbs, Spring 1958, p. 126), four more have been held, all four during the period April–June 1958. Region V (Ohio, Michigan, and West Virginia) met at the Secor Hotel in Toledo April 19 and 20. MOALMA (Region II, New York and New Jersey) held its annual technical seminar at the Biltmore in New York City May 2 and 3. On May 25 and 26, Region III (Middle Atlantic States) met at the Lord Baltimore Hotel in Baltimore. And the Congress Hotel in Chicago was the scene of the meeting of Region VI (Illinois, Eastern Missouri, Indiana, and Wisconsin) on June 14 and 15. Together with those previously reported, these sessions brought to ten the number of OALMA Regions to hold one or more meetings during the fiscal year 1957–58.

Guest at the meeting of Region V in Toledo was Glenn E. Jackson, Executive Director of OALMA. In an opening address, he reviewed the accomplishments of the Association over the past dozen years in developing professionalism in what was theretofore a trade and re-emphasized the need for sound training methods, good business practices, and high ethical standards in the continued advancement of the industry toward unquestioned status as a principled art-science with codes of behavior similar to those now generally typical of other areas of professional practice. At the business session on the following day, Jackson summarized, current work in the Artificial Limb Program, pointed up the responsibility of the individual shop for the feedback of practical information gleaned in day-to-day operations, and stressed the importance of proper conduct—appearance of the individual and his facility—and of desirable customer relations in the attainment of both stability and respect.

A unique feature of the annual Prosthetic and Orthopedic Conference of MOALMA (Region II) is its emphasis on material of particular interest to the medical profession and to the several paramedical specialties involved in the rehabilitation of amputees and cripples. The 1958 sessions included, in addition to more than a dozen technical papers and demonstrations, a special panel discussion of *Rehabilitation Problems of the Older Age Amputee.* Headed by Harry Katz, of the New York

State Division of Vocational Rehabilitation, the panel included almost a dozen well-known specialists in rehabilitation medicine, the discussion being moderated by Lester A. Smith, Assistant Executive Director of OALMA. Dr. Allen S. Russek, Associate Professor of Physical Medicine and Rehabilitation in the School of Medicine, New York University, was presented with the Association's "Annual Citation," an award of merit for outstanding work in rehabilitation and for exceptional cooperation with MOALMA members in their pursuit of professional activities in the orthotic-prosthetic field.

DR. RUSSEK

In Baltimore, at the meeting of Region III, presentations were led off by a round-table discussion of *What's in Our Future and What Can be Done About It?*, a question-and-answer period being moderated by Mr. Smith. Thereafter, William A. Tosberg, widely traveled orthotics and prosthetics expert and Technical Director of Prosthetic Services at the Institute of Physical Medicine and Rehabilitation, NYU-Bellevue Medical Center, presented a summary of the status of the limb and brace field abroad. His topic was *Orthotics and Prosthetics Worldwide—Comments on New Developments, Devices, and Overseas Conditions.*

Concluding the technical meetings on orthotics-prosthetics were two offerings. *Problems and Questions in Cerebral Palsy Bracing* was presented by Dr. Winthrop M. Phelps and C. D. Denison, both of Baltimore. *New Developments and Techniques in Prosthetics*, a presentation based on the current courses at New York University (page 159), was given by Basil Peters, of the B. Peters Company, Philadelphia. Present to summarize the latest results in the Artificial Limb Program was Dr. Harold W. Glattly, then Executive Director of the Prosthetics Research Board.

At the meeting in Chicago, Region VI offered a program of almost a dozen presentations covering, among other things, the UCLA pilot course on arm bracing (page 153), the new work at Northwestern University (page 150), and new developments in lower-extremity prosthetics as evolved at the Veterans Administration Prosthetics Center (page 170). Participating were more than half a dozen of the principals then involved in research coordinated by the Prosthetics Research Board. More than 90 persons attended a reception and banquet held on the evening of June 15.

Since the end of the season for Regional Meetings, the OALMA membership has selected for the term 1958–1959 its new set of Regional Directors. They are: Region I, Karl W. Buschenfeldt, Stoughton, Mass.; Region II, Fred J. Eschen, New York City; Region III, Basil Peters, Philadelphia; Region IV, George H. Lambert, Baton Rouge; Region V, Charles W. Rosenquist, Columbus, Ohio; Region VI, Richard G. Bidwell, Milwaukee; Region VII, Theodore W. Smith, Kansas City, Mo.; Region VIII, David C. McGraw, Shreveport; Region IX, Fred Quisenberry, Los Angeles; Region X, Herbert J. Hart, Oakland, Calif.; and Region XI, William E. Brownfield, Boise, Idaho. Plans for Regional Meetings during the coming season will be formulated after the OALMA National Assembly at Miami Beach (page 161).

OALMA-ABC Exhibit Program

Since 1954 (ARTIFICIAL LIMBS, January 1955, p. 66) the Orthopedic Appliance and Limb Manufacturers Association and the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry have cooperated in the presentation of a series of exhibits at conventions of important medical and paramedical specialists involved in the rehabilitation of amputees and cripples. Arranged by Lester A. Smith, Assistant Executive Director of both OALMA and ABC and also editor of the *Orthopedic and Prosthetic Appliance Journal*, the showings have in general been intended to acquaint physicians and other members of the rehabilitation

MR. SMITH

team with the certification movement and the drive for higher standards in artificial-limb and brace establishments, to describe the procedures by which individual technicians are certified, to elucidate the requirements for certification of a facility, and to outline the principal reference aids in the field of prosthetics-orthotics.

Many of these offerings have been cited from time to time in the *Digest* section of ARTIFICIAL LIMBS (January 1955, p. 66; May 1955, p. 98; September 1955, p. 67; Autumn 1956, p. 76; Spring 1957, p. 120). A partial list of occasions to date includes:

OALMA-ABC EXHIBIT—Typical of the continuing series of exhibits sponsored jointly by the Orthopedic Appliance and Limb Manufacturers Association and the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc., is this one presented before the Clinical Meeting of the American Medical Association in Philadelphia, December 1957. Shown, left to right, are Basil Peters, Anthony R. Cocco, and William A. Tosberg, all certified prosthetists.

American Academy of Orthopaedic Surgeons. Annual Meetings in Los Angeles, 1955; Chicago, 1956 and 1958; New York City, 1957.

American College of Surgeons. Chicago, 1958.

American Congress of Physical Medicine and Rehabilitation. Atlantic City, 1956; Los Angeles, 1957; Philadelphia, 1958.

American Medical Association. Annual Meetings in Atlantic City, 1955; Seattle, 1956. Clinical Meetings at Miami, 1954; Portland, Oreg., 1956; Philadelphia, 1957; Minneapolis, 1958.

National Rehabilitation Association. Baltimore, 1954; St. Louis, 1955; Denver, 1956; Minneapolis, 1957; Asheville, N. C., 1958.

National Society for Crippled Children and Adults. Washington, 1956; Chicago, 1957; Dallas, 1958.

Western Orthopedic Association. Phoenix, Ariz., 1956; Portland, Oreg., 1958.

During the calendar year 1959, OALMA-ABC exhibits are planned for the Annual Meeting of the American Academy of Orthopaedic Surgeons in Chicago in January, for the American Congress of Physical Medicine and Rehabilitation in Minneapolis in August and September, and for the Clinical Session of the American College of Surgeons in Atlantic City in September and October.

Certification Activities

During 1958, the American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc., the accepted qualifying agency for the limb and brace profession in the United States, continued with the organization and conduct of the usual comprehensive and oral tests for evaluation of candidates for the official titles of recognition, "certified prosthetist" (abbreviated "C.P.") and "certified orthotist" (abbreviated "C.O."). Conducted in Los Angeles, St. Louis, and Miami Beach, the 1958 examinations were administered to some 77 applicants. Of these, 38 orthotists and 18 prosthetists were found

THE SEAL OF ABC—Mark of merit in the limb and brace profession.

to meet the requirements of ABC with respect to training and experience and were awarded certificates and privileged to use in prescribed ways the official seal of the Board (see cut). The names and addresses of all currently certified personnel are to be found in ABC's *Registry of Certified Prosthetists and Orthotists.* A copy of the latest annual edition may be had upon request addressed to American Board for Certification, 919 Eighteenth St., N. W., Washington 6, D. C.

Committee on Advances in Prosthetics (OALMA)

The problem of prompt dissemination (to operating limbshops, prosthetics clinic teams, manufacturers of prosthetic devices, and others concerned) of new and useful technical information coming from the several laboratories participating in the Government-sponsored Artificial Limb Program has long been a matter of serious concern to the Orthopedic Appliance and Limb Manufacturers Association as well as to the Prosthetics Research Board. Conversely, it has been recognized that there exists among member facilities of OALMA a wealth of experience that would be useful in advancing research. From time to time heretofore the solution has been sought variously through the establishment of committees and/or subcommittees of PRB—for a while through the former Phase IV Subcommittee of PRB's Committee on Prosthetics Research and Development (last subcommittee in the well-known system of transition procedures) and for another period through PRB's onetime Committee on New Devices.

Although in the past these responsible groups have always enjoyed representation by capable persons active in the limb industry, the general emphasis on research, typical of the PRB program, has over the years tended to divert attention away from the express objectives. While the short courses in prosthetics education (UCLA and NYU, page 156) and the various publications stemming from ALP have together been of great help in making new developments available to clinic teams and others in the field, there exists additional information that would not of itself warrant establishment of a new course or development of any new publication of major proportions. In like manner, it has been difficult to elicit from clinic teams and independent limbmakers new and little-known improvements and techniques that might well exert a profound influence upon the course of laboratory investigations. Consequently, there has been evidence of a persistent deficiency in laboratory-industry cooperation.

Cognizant of these difficulties, representatives of OALMA and PRB held a series of meetings during the Annual Prosthetics Conference (page 148) for the specific purpose of developing methods for improving the mutual crossflow of information between research and practice in the field. After thorough discussion of all aspects of the problem, a number of plans were considered and shelved. Subsequently, at another meeting on July 17, it was agreed that henceforth the Orthopedic Appliance and Limb Manufacturers Association would assume the major responsibility for ensuring the exchange of information on latest developments and for coordinating Association activities having to do with the research program. Pursuant to that decision by the conferees, President John A. McCann, with the approval of the Executive Committee of the Board of Directors of OALMA, created the Committee on Advances in Prosthetics, which has as its broad mission the advancement of all approved devices and techniques toward the betterment of prosthetic services to amputees at the clinic level. To accomplish this purpose, the committee will:

MR. FILLAUER

1. receive information about the products of research conducted by the Prosthetics Research Board and attempt to devise ways and means for the expeditious application of results the better to benefit the individual amputee.
2. conduct surveys and other studies in order to obtain, for the Prosthetics Research Board, industry information that might assist in the pursuit of research programs.

Appointed as the first members of CAP were persons of extensive experience in the field of limb prosthetics. Functioning under the chairmanship of Carlton E. Fillauer, of

Chattanooga, will be M. P. Cestaro (Washington, D. C.), Fred Eschen (New York City), Charles A. Hennessy (Los Angeles), and Howard R. Thranhardt (Atlanta).

International Society of Prosthetists and Orthotists

In French, the *Union Professionelle des Bandagistes et Orthopedistes;* in German, the *Bandagisten und Orthopädiemechaniker Handwerke;* in English, the *International Society of Prosthetists and Orthotists*—whatever the language selected, the phraseology refers to an international organization of producers of artificial limbs and orthopedic appliances that was established formally at a First International Congress held in conjunction with the World Fair in Brussels May 24–26. Conceived and sponsored by the Union Professionelle des Bandagistes et Orthopedistes de Belgique, the First International Congress of Prosthetists and Orthotists enjoyed the participation of well-known limbmakers and bracemakers from both Europe and America. Representing the prosthetic and orthopedic industry in the United States and, more particularly, the Orthopedic Appliance and Limb Manufacturers Association, was George W. Fillauer, Sr., founder of Fillauer Surgical Supplies, Inc., of Chattanooga. Elected as the first president of the new international organization was Hugo Stortz, of Cologne.

Notable among the several technical papers presented was one covering the development of the orthopedic industry in Belgium and the influence that local economics has upon the quality of rehabilitation services in particular areas. Time and place of the next meeting of ISPO has not yet been announced.

Appointment for Lyman

Dr. John Lyman, Associate Professor of Engineering and Psychology at the University of California at Los Angeles and long a well-known consultant in human engineering for a number of the leading aircraft manufacturers, has been appointed head of the Engineering Artificial Limbs Project at UCLA to succeed the late Dr. Craig L. Taylor (ARTIFICIAL LIMBS, Spring 1958, p. 130). Specializing in the human requirements of engineering design, Lyman received the degree of doctor of philosophy in psychology in 1951 and joined the faculty as an assistant professor in 1952.

DR. LYMAN

In his new position, Dr. Lyman will face the formidable task of filling the shoes of his predecessor, the distinguished Taylor. He will be responsible for the continued prosecution of the research and development in upper-extremity prosthetics that has been conducted at his *alma mater* during the past dozen years. His ready familiarity with most of the work (ARTIFICIAL LIMBS, September 1955, p. 1) will serve him well in the further pursuit of the goals laid out in earlier days of the Artificial Limb Program. He is therefore especially well qualified to carry forward the investigations already so well under way.

Appointment for Perry

Dr. J. Warren Perry, formerly of the faculty of the University of Chicago, has been named director of the new prosthetics - education project at Northwestern University, it was announced last summer by Dr. Richard H. Young, Dean of North western's Medical School, and Dr. Clinton L. Compere, Academic Director of Prosthetic Research and Training and a member of PRB's Committee on Prosthetics Research and Development. Dr. Perry's position carries with it the rank of Assistant Professor in the Department of Orthopedic Surgery.

DR. PERRY

A graduate of DePauw University, Dr. Perry did his advanced work at Harvard and at Northwestern, where he received the doctorate in psychology and education. In addition to his teaching experience, he has been a

counseling psychologist for the Veterans Administration Center at Northwestern.

Dr. Perry's appointment is the first step in the organization of the new prosthetics school (page 158), which will operate under a contract between the University's Medical School and the Office of Vocational Rehabilitation of the U. S. Department of Health, Education, and Welfare. Located in the Rehabilitation Institute of Chicago (401 E. Ohio St., Chicago 11), the project will have assistance in the same building from the staffs of the Institute (directed by Dr. Bernard J. Michela) and the Prosthetics Research Center of Northwestern (directed by Colin A. McLaurin).

Although the curriculum cannot be outlined definitely at this time, the pattern will follow closely that developed originally at the University of California at Los Angeles and at New York University. The new school will serve prosthetists, orthotists, physicians, therapists, and other rehabilitation personnel from the entire Midwest. Classes are scheduled to begin in 1959.

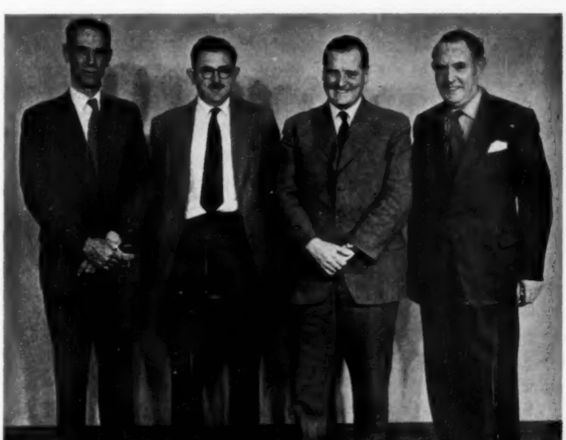
British Visitors

During the spring and early summer, participants in the Artificial Limb Program were privileged to meet with four distinguished representatives of the Roehampton Limb Fitting Centre at Queen Mary's Hospital, London. Dr. D. S. McKenzie, senior medical officer in charge, Brigadier N. A. M. Swettenham, engineer in charge of research, and Messrs. J. B. Waggott and C. P. Steeper, representing contractors at Roehampton, toured most of the research and educational centers in the United States now devoted to work in limb prosthetics. Those who had an opportunity to talk with our British colleagues were impressed with their charm, keen insight, and expert understanding of the subject of mutual interest. The opportunity of thus sharing prosthetics experience should prove to be helpful in a continued program of cooperation between the two countries.

Honors for Stewart

In mid-July, Dr. Robert E. Stewart, Director of the VA's Prosthetic and Sensory Aids Service, Washington, received a special commendation for his work in connection with the rehabilitation of the handicapped. He was cited by Dr. William S. Middleton, Chief Medical Director of the Veterans Administration, for his outstanding efficiency and leadership in the coordination of interagency efforts on behalf of disabled veterans and nonveterans alike.

A dentist by profession, and a specialist in



DISTINGUISHED VISITORS—Four distinguished representatives of the Roehampton Limb Fitting Centre at Queen Mary's Hospital, London, toured most of the research and educational establishments of the Artificial Limb Program during the period April 29 through June 25. Pictured at the New York offices of the VA's Prosthetic and Sensory Aids Service are, left to right, Brigadier N. A. M. Swettenham, engineer in charge of research; Dr. D. S. McKenzie, senior medical officer in charge; and Messrs. J. B. Waggott and C. P. Steeper, representing contractors at Roehampton.

maxillofacial restorations, Dr. Stewart has been with the Veterans Administration since 1946 and has been the director of PSAS since 1955 (ARTIFICIAL LIMBS, September 1955, p. 64). In that position he serves as the scientific officer for the VA contracts that have long constituted the principal support of the Artificial Limb Program. In addition, he is responsible for the management of the VA's own internal program of research and development in artificial limbs, orthopedic shoes, reading machines, hearing aids, and other assistive devices.

Mr. Dabelstein

Donald H. Dabelstein, Assistant Director for Program Planning and Evaluation in the Office of Vocational Rehabilitation, U. S. Department of Health, Education, and Welfare, died suddenly October 8 in Alexandria, Va., at the age of 51. Internationally known in rehabilitation circles, Mr. Dabelstein had spent his entire career in the fields of vocational guidance and special instruction. As a valued member of the Committee on Prosthetics Research and Development, he served as the liaison representative between OVR and the Prosthetics Research Board.

Born in Winona, Minn., Dabelstein was graduated from the University of Minnesota, where he received both his bachelor's and master's degrees. Having served as a high-school director of guidance at Litchfield, and later as director of special education and vocational rehabilitation for the State of Minnesota, he entered the Federal service in 1944 and had held his current position since 1947. In 1954 and 1955 he served as official adviser on rehabilitation to the United States Delegation at the congresses of the International Labor Organization in Geneva. As a member of the Policy Committee of the National Rehabilitation Association, he helped to guide the future of rehabilitation services in the world scene.

MR. DABELSTEIN

In recognition of Mr. Dabelstein's distinguished contributions in his chosen field, friends and associates in the Office of Vocational Rehabilitation have established a fund intended to support at his *alma mater*, the University of Minnesota, a memorial lecture on rehabilitation. Contributions to the Donald Dabelstein Memorial Fund, which will be received in the Office of Vocational Rehabilitation, Washington 25, will be turned over to the University, where the monies will be administered with the cooperation of OVR's National Advisory Council.

New VA Film

Recently completed by the Veterans Administration Prosthetics Center is a 26-minute color-and-sound motion picture covering the method of external finishing of wooden prostheses with a nylon stockinet-polyester laminate (ARTIFICIAL LIMBS, Spring 1958, pp. 95, 101). Designed to demonstrate step by step a technique used successfully by VAPC for the past three years, this 16-mm. film (single perforations, to be used with a magnetic sound projector) may be borrowed free of charge. Requests from responsible organizations will be honored by William M. Bernstock, Assistant Chief, Research and Development Division, Prosthetic and Sensory Aids Service, U. S. Veterans Administration, 252 Seventh Ave., New York 1, N. Y.

Demonstrators in the picture are Fred Cipolla and Francis Mulvihill, orthopedic technicians with the VA Prosthetics Center.

New ISWC Publication

Early last spring, the Committee on Prostheses, Braces, and Technical Aids of the International Society for the Welfare of Cripples inaugurated a new international technical and medical bulletin under the title *Prostheses, Braces, and Technical Aids*. Supported by the World Veterans Federation, the World Rehabilitation Fund, and the ISWC national affiliate in Denmark, the Society and Home for Cripples, this 16-page journal appears three times a year in three editions—English, French, and German, with a Spanish summary in the English edition. Editor is P.

NEW VA MOVIE—Some typical frames. Technician shown here is Fred Cipolla. *Courtesy Veterans Administration Prosthetics Center, New York City.*

Høeg Albrethsen, who is otherwise Executive Manager of the Society and Home for Cripples and the Danish National Secretary of ISWC.

Prostheses, Braces, and Technical Aids, a new added feature of the International Prosthetic Information Service, is an outgrowth of recognition by the Committee on Prostheses, Braces, and Technical Aids that the international exchange of ideas and the dissemination of information worldwide are indispensable to the advancement of services to the physically handicapped. It is distributed free to rehabilitation centers, organizations of prosthetists and orthotists, manufacturers of prostheses and related devices, individual physicians, limbmakers, bracemakers, and therapists, and to all other persons with any legitimate interest in rehabilitation work. In addition to a half dozen short articles of technical significance, the first number (that for March 1958) contained material reprinted from ARTIFICIAL LIMBS for Spring 1957 (Vol. 4, No. 1). The second (for July 1958) contained a short summary of the issue of ARTIFICIAL LIMBS for Autumn 1957 (Vol. 4, No. 2; Canadian hip-disarticulation prosthesis).

Inquiries concerning *Prostheses, Braces, and Technical Aids* should be addressed to the editor at 34 Esplanaden, Copenhagen, Denmark.

New Abstract Journal

Early last summer announcement was made of the initiation of a new monthly publication in the series of abstracting services of the Excerpta Medica Foundation (2 E. 103rd St., New York 29; 111 Kalverstraat, Amsterdam C). Entitled *Rehabilitation* (Section XIX of *Excerpta Medica*), the first issue (Vol. 1, No. 1; for July 1958) totaled 100 printed pages and comprised 314 abstracts of articles in some 20 areas of interest to rehabilitation workers (page 141). Included were abstracts of articles that have appeared in ARTIFICIAL LIMBS and of several other papers that have evolved in one way or another from the Artificial Limb Program.

The aim of this new survey journal, which was made possible by a grant from the U. S. Public Health Service, U. S. Department of Health, Education, and Welfare, is to provide a regular, up-to-date, and comprehensive review of the world literature in the field of rehabilitation. Each yearly volume is to contain about 700 pages, including a yearly author index and a cross-referenced subject index. Annual subscription fee is $15. Orders for subscriptions in the United States, Canada, and Central America should be placed through the Excerpta Medica Foundation, New York Academy of Medicine Bldg., 2 E. 103rd St., New York 29, N. Y.

Editor-in-chief of *Rehabilitation* is Dr. M. W. Woerdeman, Professor of Anatomy and Embryology in the University of Amsterdam.

Availability of AL

In the five years since its inception, ARTIFICIAL LIMBS has experienced a level of acceptance that has far exceeded preliminary expectations. By virtue of a steadily growing distribution list as well as of a continuing demand for back numbers, available copies of the journal are now for the most part quite limited. Out of print at the present time are all of the issues (January, May, and September) for 1954 (Vol. 1), that for January 1955

(first issue of Vol. 2), and that for Spring 1956 (Vol. 3, No. 1). Supplies of Vol. 2, No. 2 (May 1955), and of Vol. 3, No. 2 (Autumn 1956), are fast dwindling.

Early in 1958, bound runs of the journal (Vols. 1 and 2 bound together, Vols. 3 and 4 bound together) were supplied to all laboratories and institutions participating in the Artificial Limb Program. These are available for consultation locally. In addition, the Prosthetics Research Board retains several bound sets for short-term loan to any responsible party. Requests for loans should be addressed to the Prosthetics Research Board, National Academy of Sciences, 2101 Constitution Ave., Washington 25, D. C. Borrowed volumes are shipped postpaid, but it is expected that return postage shall be paid by the borrower.

Artificial Limbs

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PROSTHETICS RESEARCH BOARD

NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

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NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL

The National Academy of Sciences—National Research Council is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare.

The Academy was established in 1863 under a Congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the Federal Government in scientific matters. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency.

The National Research Council was established by the Academy in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the Academy in service to the nation, to society, and to science at home and abroad. Members of the National Research Council receive their appointments from the President of the Academy. They include representatives nominated by the major scientific and technical societies, representatives of the Federal Government, and a number of members-at-large. In addition, several thousand scientists and engineers take part in the activities of the Research Council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the Academy and its Research Council thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the Government, and to further the general interests of science.